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EMERGENCY BRAKING ON ELECTRIC CARS

BY

D. D. EWING

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BULLETIN No 13

ENGINEERING EXPERIMENT STATION
LAFAYETTE, INDIANA

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Purdue University, LaFayette, Indiana

BULLETIN NO. 13
ENGINEERING EXPERIMENT STATION

EMERGENCY BRAKING
ON
ELECTRIC CARS

By
D. D. EWING
Professor of Electric Railway Engineering

PURDUE UNIVERSITY
LAFAYETTE, INDIANA
JULY, 1923

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EMERGENCY BRAKING
ON
ELECTRIC CARS

Preface

At one of the 1923 meetings of the Engineering Council of the Central Electric Railway Association the question. "What is the best practice for making emergency stops to avoid accidents?", was brought up for discussion. The resulting discussion showed such a variance in practice and so much ambiguity in rule books that it was quite apparent that the question was one that had not received sufficient attention at the hands of operating companies. In order to bring the matter to the attention of the Association, Mr. H. C. DeCamp presented a paper on the subject at the Annual Meeting of the Association, held in Louisville, Ky., January 18 and 19, 1923. As result of the paper and discussion thereon, a committee of six men, four representing the operating companies, one representing the air brake manufacturers and one representing Purdue University as a non-partisan interest, was appointed to investigate the problem.

This committee made a series of tests on four electric cars. A brief report of these tests which was presented at the mid-summer meeting of the Association held at Cedar Point, Ohio, July 18, 19, and 20th, is reproduced in Section I of this bulletin. This report is merely a summary of an extensive detail study of the data taken during the test. Owing to the importance of the subject, the value of the detail data from a technical standpoint, and the fact that the test and the analysis of the test data was under the direction of a member of the Purdue University Staff, the Engineering Experiment Station of Purdue University agreed to cooperate in the investigation to the extent of preparing and publishing a complete report of the investigation.

This bulletin therefore is the report of a cooperative investigation on the subject of "Emergency Braking on Electric Cars" in which:

(1) Electric railway companies representing the Central Electric Railway Association furnished cars, track, power, crews, transportation, shop facilities and certain traveling expenses.

(2) The Westinghouse Traction Brake Company furnished the bulk of the testing equipment and engineers to assist with the details of the test.

(3) Purdue University Engineering Experiment Station furnished some testing equipment, technical assistants for the test work, and prepared and published the complete report of the investigation.

As shown by the list of names in the next section the test was witnessed by a number of men representing public utility commissions, electric railway associations, operating companies and railway equipment manufacturers.

The author wishes to express his appreciation of the hearty cooperation and assistance of his fellow committee members: Mr. S. W. Greenland, Vice President and General Manager, Indiana Service Corporation, Ft. Wayne, Indiana, Mr. S. D. Hutchins, Westinghouse Traction Brake Company, Columbus, Ohio, Mr. C. A. Brown, Master Mechanic, Community Traction Company, Toledo, Ohio, Mr. G. K. Jeffries, General Superintendent, Terre Haute, Indianapolis and Eastern Traction Company, Indianapolis, Indiana and Mr. H. C. DeCamp, Assistant General Manager, The City Railway Company, Dayton, Ohio.

He also desires to express his appreciation to Messrs. P. B. McGinnis and C. W. Melephant of the Westinghouse Traction Brake Company for their assistance and counsel in connection with the test work, to Mr. J. S. Y. Fralich, of the Westinghouse Traction Brake Company for his assistance and counsel in the preparation of the report and to Messrs. W. L. Galey, M. Aldrich and W. E. Blowers, Senior Students in Electrical Engineering, Purdue University, for their untiring assistance in connection with the test work and the preparation of this bulletin.

SECTION I

Report to the Central Electric Railway Association:

As a result of the presentation at the Louisville Convention of the Association last winter, by H. C. DeCamp, of a paper on the subject of "Emergency Stops," the motion was passed: "That a committee of five be appointed to look into this question very thoroughly."

The undersigned were appointed members of the committee and at this time beg to submit the following report:

After several informal conferences and considerable correspondence, the committee decided to make a series of tests on several types of cars during the week beginning Sunday, May 13. Emergency stop tests, extending through this week, were made on:

(a)—Interurban car, double truck, four motors.
(b)—City car, double truck, four motors.
(c)—City car, double truck, two motors.
(d)—Birney Safety car.

Conclusions. As the result of a careful analysis of the test data, the following conclusions were reached:

(1) There is no one best way to stop any car in an emergency. In general, the best way will depend somewhat on the type of brake and motor equipment.

(2) As a broad rule, subject to occasional exceptions, it may be said that the best way to stop a car equipped with air-brakes is to apply emergency air and sand, simultaneously throwing the controller to the off position.

(3) The electrical methods of braking, reversed motors and bucking motors, subject the equipment to very severe strains. Because of the abruptness with which the braking force is applied, the value of these methods in emergency braking is more apparent than real, except in those cases in which the air-brakes from some cause are inoperative.

(4) Of the two electrical methods, reversed motors and bucking motors, the reversed motors method is the most effective.

(5) If the motors are reversed in conjunction with emergency air and sand, skidding invariably results, and even under good rail conditions, the results are not superior to those obtained using air alone.

(6) The electric braking methods are more likely to produce erratic results than the emergency air, and for this reason should not be resorted to as a general practice.

(7) Because the rail conditions under which these tests were made, were better than those ordinarily obtaining on city streets, the results should be regarded as minimums rather than averages or maximums.

(8) The best way to stop a Birney Safety car in an emergency is for the motorman to raise his hand from the controller handle.

This is true only when the car is running with brakes released. With brakes applied the brake valve should be thrown to the emergency position.

Cars and Track. A brief summary of the details of the four cars tested is given in Table 1. The test track selected was on the long and approximately level track of the Lebanon-Crawfordsville Branch of the Terre Haute, Indianapolis & Eastern Traction Co., and consisted of a stretch of track about one mile in length just west of Pettigrew substation. The profile of the test track shows that the elevation one mile west of the substation is only one foot higher than that at the substation. Aside from the minor undulations, the track may be considered as level. During the first two days of the test, the weather was unsettled and the track was wet at times. Mostly, however, the rails were dry and in excellent condition for braking tests.

TABLE 1.
SUMMARY OF CAR DATA

Car No.	61	1026	244	55
Owner	T.H.I.&E.T.Co.	I.S.R.Co.	Ind. Ser. Corp.	N.I.P. Co.
Type	Interurban	City	City	Birney
Weight (empty)	77400 lb.	39700 lb.	34200 lb.	15200 lb.
No. Trucks	2	2	2	1
No. Motors	4	2	4	2
Kind of Motors	W-304	W-310-E-2	W-506	G.E.-264
Gear Ratio	24-63	15-69	14-78	13-74
Type Control	K	K	K	K
Type of Brakes	Straight & Automatic	Straight	Straight	Safety
Wheel Diam.	35 19/32 in.	31 1/8 in.	29 3/4 in.	24 5/8 in.
Per Cent Braking Power at 50 lb. Brake Cylinder Pressure (Car Empty)	102.1	58.0	83.5	167.0

Details of the Test. Cars 61, 1026 and 244 were assembled at Lebanon, May 13, and this day and the one following were spent in making them ready for the test. Car 55 reached Crawfordsville, May 16, While under test each car was equipped with:

(1) A chronograph, recording (a) time in half-seconds and (b) car wheel revolutions.

(2) A trainagraph, recording brake cylinder and other pressures, and time, the time mechanism being operated from the chronograph.

ERRATA SHEET

After this bulletin had been printed it was discovered that an error had been made in determining the effective lengths of some of the brake levers on Car No. 1026. The error in no way affects the value of the test data but merely alters the description of the condition of the car at the time of the test by the following corrections: Page 14, Table 1, third column, last line, change 58 to 88.7. Page 33, Fig. 11. Front truck, front axle, right wheel (upper left corner) change 3180 lb. to 4369 lb.; left wheel, 2875 lb. to 4069 lb.; rear axle, right wheel, 3679 lb. to 4460 lb., $11\frac{1}{4}$ in. to $19\frac{1}{8}$ in. and $20\frac{1}{4}$ in. to $28\frac{1}{4}$ in., left wheel 3505 lb. to 4669 lb., $10\frac{7}{8}$ in. to $19\frac{1}{8}$ in. and $20\frac{1}{4}$ in. to $28\frac{5}{8}$ in. Transpose levers attached to brake cylinder. Rear truck, front axle, right wheel, change 2709 lb. to 4661 lb., $9\frac{7}{8}$ in. to 19 in., 19 in. to $28\frac{1}{4}$ in., left wheel, 2680 lb. to 4609 lb., $9\frac{15}{16}$ in. to 19 in., 19 in. to $28\frac{1}{16}$ in.; rear axle, right wheel, change 2162 lb. to 4667 lb., left wheel, 2161 lb. to 4669 lb. Page 32, Table 11, fourth line, change 18.5 to 27.5. Sixth line, change 11.5 to 11.1, 29.56 to 29.1, and 19.62 to 28.2. Seventh line, change 7.31 to 7.06 and 9.69 to 9.2.

Page 35, Table 14. Change fifth and sixth columns to read:

Braking Power	
Pounds	Per Cent
705	1.775
35240	88.7
705	1.85
35240	83.0
42300	99.5
44109	103.5
37869	89.0
44603	105.0

Page 47, Table 19. Change last two columns for Car No. 1026 to read:

Braking Power	
Pounds	Per Cent
705	1.54
35240	77.00
42300	92.5
705	1.45
35240	72.5
42300	87.0

Page 83, paragraph on "Brake Efficacy", Change 0.295 to 0.192 and 0.194 to 0.127.

Page 97, paragraph on "Brake Efficacy", Change 0.0104 to 0.104.

(3) A graphic recording speedmeter with a time pen operated from the chronograph.

(4) An electrically operated counter for counting car wheel revolutions.

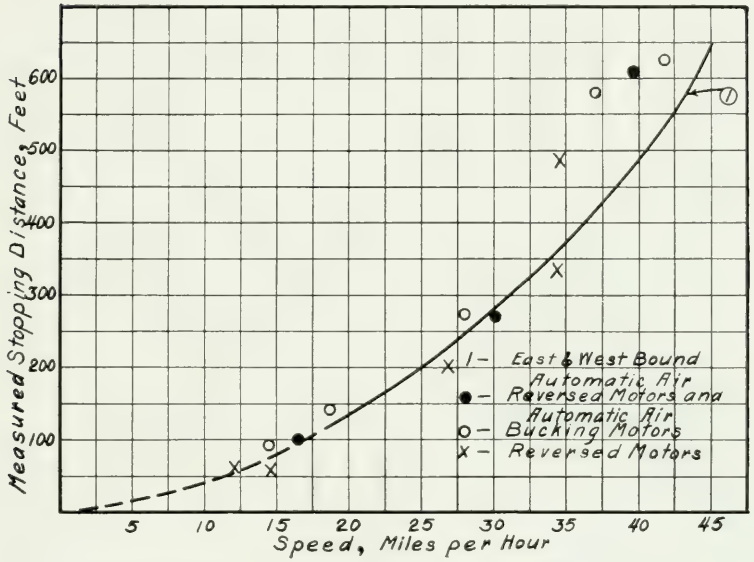


Fig. 1—Relation Between Stopping Distance and Initial Speed, Interurban Car No. 61, for the Various Methods of Braking.

These instruments were so connected as to practically eliminate personal errors in timing. Time was also measured with stop watches, usually by more than one observer. A shotgun was used to mark the track, and the report of the gun was the emergency signal to the motorman. This plan was decided upon in order to take into account the personal element of the motorman in reacting to a signal. The stopping distance was measured with a surveyor's steel tape.

The more important data resulting from the tests are shown in Tables 2, 3, 4 and 5 and the speed-distances curves, Fig. 1, 2, 3, and 4.

The tables show also the general conditions under which the tests were run. On the curve sheets the lines drawn to represent the data for emergency air braking are average lines, the points from which they were drawn not being shown. For comparative purposes, these lines were drawn as reference lines and the points for the other tests were simply marked on the sheets, no curves being drawn. In comparing the data, therefore, it must be remembered that individual points for the air-brake curves fall both below and above the average line.

TABLE 2

Interurban Car No. 61

SUMMARY OF TEST DATA

Run No.	Kind[1] of Braking	Speed M.P.H.	Stop Time, Seconds	Stop Distance, Feet	Avg. Braking Rate M.P.H. P.S.	Direction of Run	Brake Cylinder Pressure Lb. Per Sq. In. Gauge	Load (People)	Remarks
A-1	A.	20.0	6.5	137.0	3.09	West	60	26	Dry Track
A-2	A.	27.1	8.4	210.3	3.21	West	59	26	Dry Track
A-3	A.	30.6	10.8	309.1	2.82	West	58	26	Dry Track
A-4	A.	37.0	12.8	427.7	2.90	West	58	26	Dry Track
A-5	A.	39.4	13.9	475.8	2.83	West	57	26	Dry Track
A-6	A.	45.3	16.6	672.6	2.74	West	57	26	Dry Track
A-13	A.	18.5	7.1	131.7	2.61	East	58	26	Dry Track
A-7	A.	26.2	9.2	261.2	2.84	East	57	26	Dry Track
A-9	A.	28.0	8.6	223.5	3.25	East	58	26	Damp Track
A-8	A.	39.2	12.6	440.6	3.12	East	57	26	Dry Track
A-12	S.&A.	12.7	5.5	78.0	2.33	East	-	26	Dry Track
A-11	S.&A.	25.3	9.8	247.6	2.57	East	68	26	Rain
A-10	S.&A.	41.7	15.6	605.4	2.66	East	69	26	Rain
A-14	S.&A.	48.9	17.6	746.2	2.78	East	70	26	Dry Track
A-29	S.&A.	41.8	20.1	795.0	2.09	East	49	26	Dry Track. Reduced Pressure
A-15	S.	46.9	15.8	636.1	2.97	East	70	26	Dry Track
A-17	R.M.	12.1	5.4	64.5	2.23	East	-	26	Two points on controller
A-16	R.M.	14.5	5.5	63.0	2.64	East		26	Two points on controller
A-22	R.M.	26.9	9.3	201.8	2.90	East		26	Two points on controller
A-21	R.M.	34.2	14.8	335.0	2.32	East		26	Two points on controller
A-23	R.M.	34.6	16.4	489.6	2.12	East		26	Two points on controller
A-19	B.M.	14.3	11.3	91.8	1.27	East		26	Dry Track
A-18	B.M.	18.6	10.3	141.6	1.79	East		26	1 point on controller C.B. thrown
A-20	B.M.	27.8	19.1	270.5	1.45	East		26	Dry Track
A-24	B.M.	36.7	21.0	580.3	1.75	East		26	Dry Track
A-25	B.M.	41.5	19.8	623.6	2.10	East	-	26	Dry Traxk
A-28	R.M. +A.	16.4	5.7	103.0	2.90	East	57	21	Two points on controller
A-27	R.M. +A.	29.9	10.2	274.3	2.94	East	58	21	Two points on controller
A-26	R.M. +A.	39.5	18.4	609.3	2.14	East	57	21	Two points on controller

[1]NOTE,—
A. Automatic Air, Emergency and Sand
S.&A. Straight and Automatic Air, Emergency and Sand
S. Straight Air, Emergency and Sand
R.M. Reversed Motors
B.M. Bucking Motors
R.M. +A. Reversed Motors Plus Automatic Air, Emergency and Sand

TABLE 3
City Car No. 244
SUMMARY OF TEST DATA

Run No.	Kind[1] of Braking	Speed M.P.H.	Stop Time, Seconds	Stop Distance, Feet	Avg. Braking Rate M.P.H. P.S.	Direction of Run	Brake Cylinder Pressure Lb. Per Sq. In. Gauge	Load (People)	Remarks
B-2	E.	10.3	5.3	56.2	1.97	East	52	24	Sand on front 4 wheels. Wet track
B-1	E.	16.1	6.4	97.8	2.50	East	53	24	Sand on front 4 wheels. Wet track
B-3	E.	18.8	8.7	152.2	2.17	East	52	24	Sand on 4 front wheels. Wet track
B-4	E.	23.7	10.8	228.6	2.20	East	51	24	Sand on 4 front wheels. Wet track
B-5	E.	26.8	11.2	275.5	2.40	East	52	24	Sand on 4 front wheels. Wet track
B-10	E.	5.7	2.8	14.0	2.00	East	62	23	Rain few drops
B-6	E.	13.0*	4.7	65.6	2.76	East	61.0	24	Dry track
B-7	E.	14.2	4.8	77.8	2.98	East	59.0	24	Dry track
B-8	E.	21.3	7.2	139.3	2.98	East	60.5	24	Rain few drops
B-9	E.	28.8	10.4	264.5	2.77	East	56.0	23	Rain few drops
B-18	E.	4.8	2.1	11.4	2.25	West	62.0	20	Dry track
B-14	E.	5.1	1.9	11.5	2.54	West	62.0	22	Rain few drops
B-16	E.	5.1	2.6	12.5	1.91	West	61.5	20	Dry track
B-17	E.	5.1	2.1	12.7	2.42	West		20	Dry track
B-15	E.	5.3	2.1*	14.5	2.52	West	61.0	20	Rain few drops
B-13	E.	16.7	5.5	88.9	3.04	West	60.0	21	Rain few drops
B-12	E.	19.7	6.9	129.9	2.86	West	60.0	21	Rain few drops
B-11	E.	27.2	10.0	238.7	2.70	West	59.0	21	Rain few drops
B-20	R.M.	4.8	2.7	10.9	1.76	West		20	Dry track. One point on controller
B-19	R.M.	5.7	1.2	13.7	4.71	West		20	Dry track. Two points on controller
B-21	R.M.	11.4	3.5	39.8	3.14	West		20	Two points on controller. Breaker blew
B-22	R.M.	15.4	5.9	39.8	2.62	West		20	Dry track. One point on controller
B-25	R.M.	19.3	6.1	112.0	3.18	West		18	Dry track. One point on controller
B-26	R.M.	24.7	8.2	152.6	3.02	West		17	Breaker blew. E. with sand
B-24	R.M.	25.3	6.8	136.0	3.73	West		20	Dry track. One point on controller
B-23	R.M.	26.8	10.4	200.5	2.58	West		22	Dry track. One point on controller
B-30	B.M.	7.8	6.1	24.8	1.28	West		20	Dry track
B-29	B.M.	11.9	7.0	70.6	1.70	West		20	Dry track
B-28	B.M.	20.2	9.8	165.0	2.06	West		20	Dry track
B-27	B.M.	25.3	11.6	219.7	2.19	West		20	Dry track
B-31	R.M. + E.	16.8	4.0	65.0	3.87	West		19	Air last with sand
B-32	R.M. + E.	18.4	7.1	120.0	2.58	West	64.0	19	Air first without sand
B-34	R.M. + E.	22.8	7.5	182.6	3.03	West	65.0	14	Air first with sand
B-33	R.M. + E.	30.6	11.1	293.0	2.76	West	60.0	20	1 in. flat spot on wheels

[1]NOTE.— E. Emergency Air and Sand
R.M. Reversed Motors
B.M. Bucking Motors
R.M. + E. Emergency Air and Sand Plus Reversed Motors

*Starred readings.—Miles per hour taken from corrected speedmeter readings and time in seconds from the mean of stop watch readings

TABLE 4

City Car No. 1026

SUMMARY OF TEST DATA

Run No.	Kind[1] of Braking	Speed M.P.H.	Stop Time, Seconds	Stop Distance, Feet	Avg. Braking Rate M.P.H.P.S.	Direction of Run	Brake Cylinder Pressure Lb. Per Sq. In. Gauge	Load (People)	Remarks
C-6	E.	9.1	3.1	27.7	2.94	East	62.5	12	Dry rail
C-3	E.	9.9	2.7	29.0	3.67	East	63.0	12	Dry rail
C-4	E.	15.2	4.3	67.8	3.54	East	62.0	12	Dry rail
C-5	E.	22.0	6.0	126.0	3.66	East	62.0	12	Dry rail
C-7	E.	25.7	7.1	166.8	3.62	East	62.5	12	Dry rail
C-2	E.	31.5	8.5	243.1	3.70	East	63.0	12	Dry rail
C-8	E.	9.4	3.2	33.8	2.94	East	55.0	12	Dry rail
C-9	E.	9.7	4.0	32.0	2.42	East	54.0	12	Dry rail
C-10	E.	13.8	4.6	66.0	3.00	East	----	12	Dry rail
C-11	E.	15.6	5.1	74.0	3.06	East	54.0	12	Dry rail
C-12	E.	23.2	7.1	144.4	3.27	East	54.0	12	Dry rail
C-13	E.	26.8	8.8	205.6	3.04	East	54.0	12	Light rain
C-14	E.	31.0	9.8	266.0	3.16	East	54.0	12	Light rain
C-15	R.M.	8.6	6.5	49.3	1.32	East	--	12	Dry rail. One point on controller
C-16	R.M.	9.5	9.4	59.0	1.01	East	---	11	Dry rail. One point on controller
C-18	R.M.	14.2	12.9	138.6	1.10	East	--	11	Dry rail. One point on controller
C-17	R.M.	15.2	----	-----	----	East	---	11	Pulled trolley. Overhead on fire
C-20	B.M.	8.7	6.0	53.0	1.45	East	--	11	Dry rail. Pulled trolley instead of throwing breaker
C-21	B.M.	14.4	9.0	122.0	1.60	East	-	11	Dry rail. Pulled trolley instead of throwing breaker
C-23	B.M.	21.0	15.1	272.8	1.39	East	.	14	Dry rail. Pulled trolley instead of throwing breaker
C-25	R.M. +E.	11.0	3.6	38.4	3.06	East	63.0	14	Dry rail. No sand
C-26	R.M. +E.	15.4	4.4	69.0	3.50	East	63.0	14	Dry rail. Slide at end of 43 feet
C-27	R.M. +E.	22.5	6.5	133.5	3.46	East	63.0	14	Dry rail. Slid at end of 75 feet
C-28	R.M. +E.	28.2	8.5	218.1	3.32	East	63.0	14	Dry rail. Slid at end of 69 feet. (Breaker blew)

C-30	E.	10.6	3.1	36.0	3.42	West	62.5	12	Dry rail
C-29	E.	12.9	4.1	52.4	3.15	West	63.0	12	Dry rail
C-31	E.	19.4	5.9	100.0	3.29	West	62.5	12	Dry rail
C-33	E.	26.7	7.7	194.2	3.46	West	63.5	12	Dry rail
C-34	E.	8.5	3.0	33.0	2.82	West	55.5	12	Dry rail
C-35	E.	23.1	6.9	138.9	3.35	West	53.5	12	Dry rail
C-36	E.	28.3	8.7	213.5	3.26	West	54.0	12	Dry rail
C-37	R.M. + E.	8.6	3.7	28.5	2.32	West	61.5	12	Dry rail
C-38	R.M. + E.	22.4	6.2	118.9	3.62	West	63.0	12	Overhead on fire. Sliding 36 feet after start
C-39	R.M. + E.	27.2	7.2	174.5	3.72	West	62.5	12	Overhead on fire. Sliding 36 feet after start
C-40	R.M.	21.0	14.6	279.5	1.44	West	----	12	Breaker blew. B. M. stop
C-41	R.M.	--	7.0	67.0	----	West	---	12	Breaker blew. B. M. stop
C-42	B.M.	8.5	6.0	50.0	1.42	West	- -	12	Trolley pulled instead of throwing breaker
C-43	B.M.	20.8	12.5	191.2	1.66	West	---	12	Trolley pulled instead of throwing breaker
C-44	B.M.	27.8	22.2	418.5	1.25	West	- -	12	Trolley pulled instead of throwing breaker

NOTE.—
E. Emergency Air and sand
R.M. Reversed Motor
B.M. Bucking Motors
R.M. + E. Reversed Motor plus Emergency Air and Sand

TABLE 5

Birney Safety Car No. 55

SUMMARY OF TEST DATA

Run No.	Kind[1] of Braking	Speed M.P.H.	Stop Time, Seconds	Stop Distance, Feet	Avg. Braking Rate M.P.H. P.S.	Direction of Run	Brake Cylinder Pressure Lb. Per Sq. In. Gauge	Load (People)	Remarks
D-52	Hands Up	8.0	2.3	21.0	3.48	East	67.0	29	
D-6	Hands Up	8.5*	2.8*	25.6	3.04	East	----	--	
D-53	Hands Up	14.5	3.9	57.6	3.94	East	66.5	29	
D-55	Hands Up	19.2	4.8	84.0	3.99	East	67.0	29	
D-54	Hands Up	19.3*	5.0*	92.8	3.27	East	65.0	29	
D-56	Hands Up	24.2	5.9	137.8	4.22	East	65.0	29	
D-57	Hands Up	26.8	6.4	157.3	4.17	East	65.0	29	
D-26	Hands Up	7.5	2.0	17.5	3.79	West	67.5	32	
D-9	Hands Up	8.1	2.5	21.0	3.19	West	68.0	33	
D-12	Hands Up	8.3*	3.8	20.6	2.19	West	69.0	33	
D-13	Hands Up	8.9	2.4	23.0	3.78	West	64.0	33	
D-25	Hands Up	9.6	2.6	27.8	3.64	West	64.0	32	
D-14	Hands Up	12.1	2.9	37.0	4.17	West	67.0	33	
D-10	Hands Up	13.8	3.7	53.7	3.73	West	67.5	33	
D-15	Hands Up	14.5	3.3	56.0	4.39	West	66.0	33	
D-27	Hands Up	15.7	3.5	56.2	4.41	West	68.5	32	
D-28	Hands Up	16.7	3.7	63.5	4.38	West	67.0	32	
D-29	Hands Up	18.4	4.6	81.1	4.02	West	66.0	32	
D-30	Hands Up	20.9	4.9	98.2	4.22	West	67.0	32	
D-24	Hands Up	25.5	5.9	134.9	4.29	West	64.0	33	
D-31	Hands Up	7.7	2.3	20.9	3.56	West	58.0	32	
D-32	Hands Up	14.5	3.7	59.0	4.06	West	58.5	32	
D-33	Hands Up	20.3	4.9	94.2	4.17	West	58.5	33	
D-34	Hands Up	23.5	6.3	137.3	4.05	West	56.5	33	
D-35	Hands Up	24.6	6.4	149.5	3.71	West	57.0	32	
D-41	R.M.	7.5	3.0	26.0	2.64	West	----	34	One point on controller
D-42	R.M.	14.2	13.7	106.3	1.11	West	----	33	One point on controller
D-43	R.M.	14.6	8.1	85.6	1.87	West	---	33	One point on controller
D-44	R.M.	19.3	10.5	167.5	1.88	West	----	33	End of 45 ft., wheels start backwards. One point on controller

D-45	B.M.	8.2	6.1	56.4	1.40	West	- - -	33	Car slid 12 ft.
D-46	B.M.	14.7	8.7	122.0	2.26	West	- - -	33	Car slid 54 ft.
D-47	B.M.	19.4	12.2	206.6	1.67	West	- - -	33	Car slid 122 ft.
D-49	E.	8.8	2.6	28.5	3.59	East	65.0	29	
D-5	E.	8.9*	3.1*	30.0	2.87	East	69.0	29	
D-50	E.	14.5*	4.0*	61.0	3.62	East	64.5	29	
D-51	E.	20.2	5.3	105.6	3.77	East	64.5	29	
D-48	E.	28.8	8.6	261.8	3.31	East	61.0	29	
D-17	E.	8.5	2.3	33.0	3.70	West	65.0	33	
D-18	E.	8.5	2.2	25.0	3.86	West	63.0	33	
D-23	E.	10.1	2.5	29.5	4.18	West	65.0	33	
D-19	E.	14.5	3.8	54.6	4.10	West	66.0	33	
D-16	E.	16.2*	3.8*	63.7	4.26	West	62.0	33	
D-20	E.	18.3	4.0	76.5	4.54	West	66.0	33	
D-21	E.	23.4	5.4	125.4	3.57	West	62.0	33	
D-22	E.	24.4	5.6	134.1	4.23	West	65.0	33	
D-36	E.	10.7	2.7	41.0	4.12	West	56.5	32	
D-37	E.	14.0*	2.9*	65.0	4.82	West	56.5	32	
D-38	E.	15.6	4.2	68.5	3.45	West	56.5	32	
D-40	E.	19.4	5.3	98.6	3.67	West	56.5	34	
D-39	E.	27.1	7.2	175.3	3.50	West	56.0	34	Started sand in one car length
D-59	Hands Up	8.4	2.2	21.0	4.05	East	68.0	9	
D-58	Hands Up	10.0	2.4	28.0	4.21	East	66.5	14	
D-60	Hands Up	14.4	3.4	51.8	4.24	East	67.0	9	
D-61	Hands Up	20.3	4.7	89.4	4.29	East	66.0	9	
D-62	Hands Up	27.0	6.6	169.6	4.37	East	64.0	9	
D-64	Hands Up	8.4	2.1	21.5	3.98	East	59.0	9	
D-63	Hands Up	13.4	3.5	50.6	3.83	East	57.5	9	
D-65	Hands Up	20.2	5.2	100.1	4.02	East	57.0	9	
D-66	Hands Up	27.5	6.6	167.6	4.20	East	56.0	9	

*Speed taken from the calibration curve of the speed meter and time taken by stop watch

[1]NOTE—Hands Up—Dead Man's Handle Action Controller
E. Emergency Air and Sand
B.M. Bucking Motor
R.M. Reversed Motors

In the tests, with the Birney car, which are marked "Hands Up," the motorman simply raised his hand off the controller handle when he received the emergency stop signal.

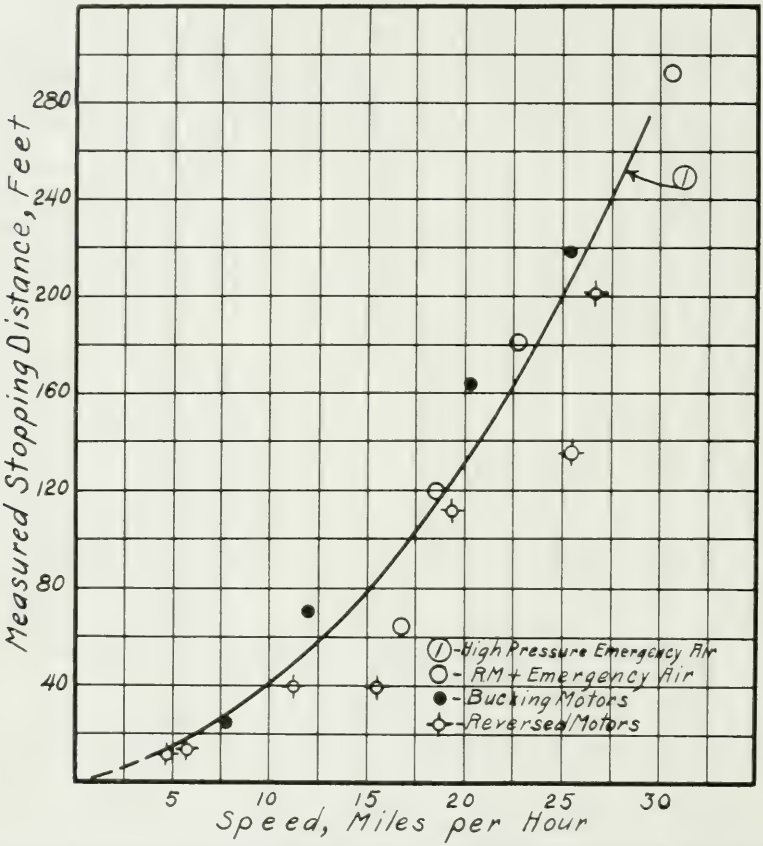


Fig. 2—Relation Between Stopping Distance and Initial Speed, City Car No. 244, for the Various Methods of Braking.

It will be noted that of the four cars, car No. 244 was the only one in which the method of reversed motors showed any decided advantages. It may be pointed out, however, that the braking power of this car is about 80 per cent, or considerably below the commonly accepted standards of good braking practice.

The speeds and stop times are those determined from the chronograph records. Owing to the effect of the thickness of the driving belt, and belt slippage, the recording speedmeter gave only approximate results, and was used only as a guide while making the tests.

The tests were run under the direction of D. D. Ewing of Purdue University, assisted by P. B. McGinnis and C. W. Mele-

phant of the Westinghouse Traction Brake Company. Other representatives of the Traction Brake Company, three students from Purdue University, and a number of those witnessing the tests assisted with the detail test work.

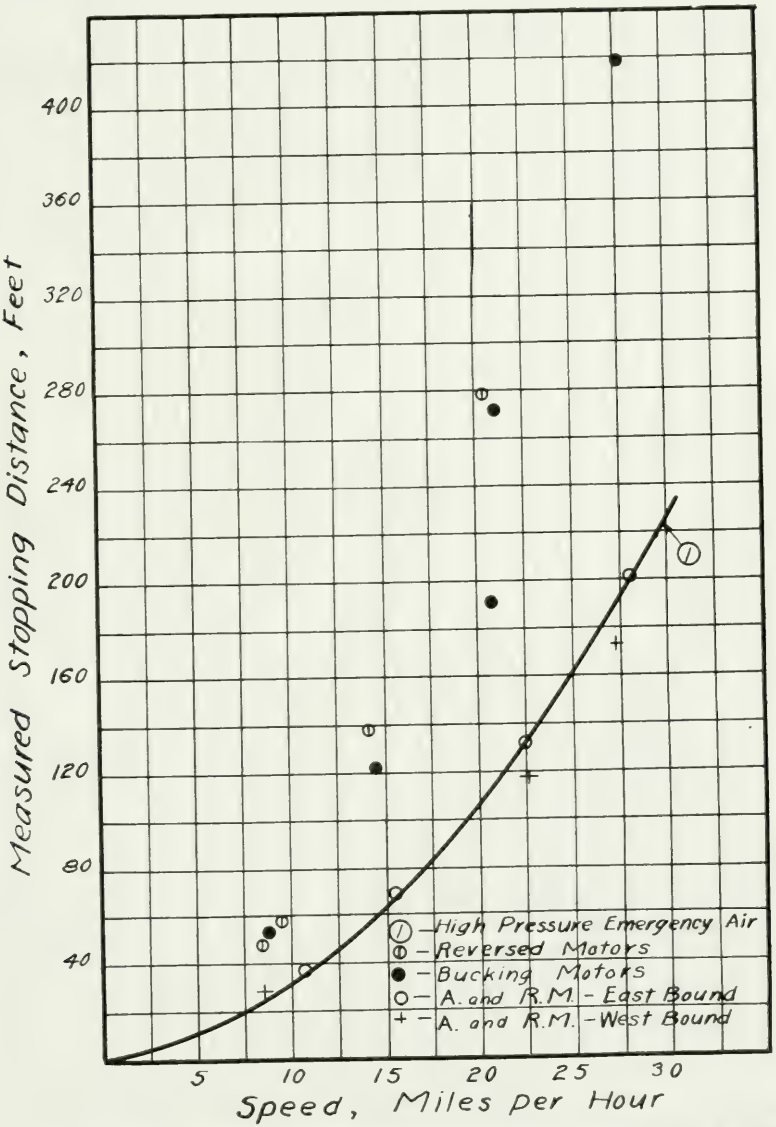


Fig. 3 —Relation Between Stopping Distance and Initial Speed, City Car No. 1026, for the Various Methods of Braking.

The analysis of the data has been under the direction of Prof. Ewing, assisted by Mr. J. S. Y. Fralich of the Westinghouse Traction Brake Company. Owing to the importance of the detail data taken in addition to the data on stopping distance and time, the Engineering Experiment Station of Purdue University has offered to cooperate in these tests by analyzing and publishing the detail data. This work is now in process, and is sufficiently advanced to permit drawing of the general conclusions contained in an earlier paragraph.

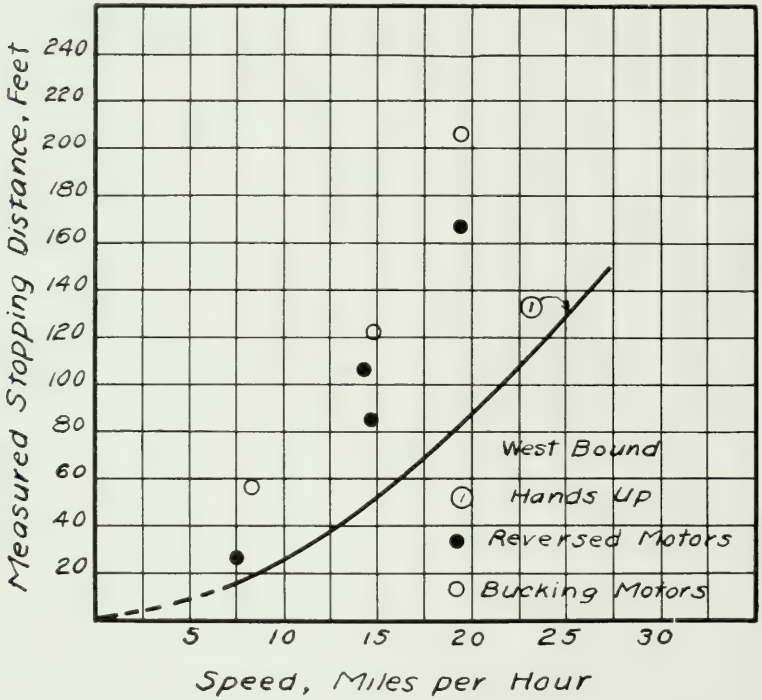


Fig. 4—Relation Between Stopping Distance and Initial Speed, Birney Car No. 55, for the Various Methods of Braking.

Following are the names of those who witnessed or participated in the tests, some of them being present only part of the time:

S. W. Greenland, Vice-President and General Manager, Indiana Service Corporation, Ft. Wayne, Indiana.

G. K. Jeffries, General Superintendent, Terre Haute, Indianapolis & Eastern Traction Co., Indianapolis, Ind.

H. C. DeCamp, Assistant General Manager, City Railway Company, Dayton, Ohio.

R. W. Emerson, General Manager, Cleveland Railway Company, Cleveland, Ohio.—Representing the American Electric Railway Association.

C. H. Clark, Engineer, Maintenance of Way, Cleveland Railway Company, Cleveland, Ohio.—Representing the American Electric Railway Association.

Terrence Scullin, Superintendent of Equipment, Cleveland Railway Company, Cleveland, Ohio.—Representing the American Electric Railway Association.

L. E. Earlywine, Secretary, Central Electric Railway Association, Indianapolis, Indiana.

D. E. Mathews, Chief Inspector, Public Service Commission, of Indiana, Indianapolis, Indiana.

H. M. Evans, Public Utilities Commission of Ohio, Columbus, Ohio.

T. H. Burke, Public Utilities Commission of Ohio, Columbus, Ohio.

M. B. Knox, Western Representative, Electric Railway Journal, Chicago, Illinois.

Charles Ives, General Electric Company, Erie, Pa.

E. C. Gunn, General Electric Company, Cincinnati, Ohio.

G. A. Wright, Westinghouse Electric & Mfg. Company, Indianapolis, Indiana.

Fred Connelly, Traveling Master Mechanic, Union Traction Company of Indiana, Anderson, Indiana.

John W. Osborn, Superintendent of Equipment, Terre Haute, Indianapolis & Eastern Traction Company, Lebanon, Ind.

Faye Caldwell, Superintendent, Crawfordsville Division, Terre Haute, Indianapolis & Eastern Traction Company, Crawfordsville, Indiana.

Harry Coleman, Equipment Inspector, Indiana Service Corporation, Fort Wayne, Indiana.

C. E. Masterson, Northern Indiana Power Company, Kokomo, Indiana.

E. B. Harding, Dispatcher, Terre Haute, Indianapolis & Eastern Traction Company, Lebanon, Indiana.

P. B. McGinnis, Representative, Westinghouse Traction Brake Company, Chicago, Illinois.

B. M. Hartsock, Westinghouse Traction Brake Company, Columbus, Ohio.

Lawrence Wilcox, Westinghouse Traction Brake Company, Chicago, Illinois.

C. W. Melephant, Test Engineer, Westinghouse Air-Brake Company, Wilmerding, Pa.

Harvey Wood, Mechanical Expert, Westinghouse Traction Brake Company, Chicago, Illinois.

D. D. Ewing, Professor of Electric Railway Engineering, Purdue University, LaFayette, Indiana.

W. L. Galey, Student, Purdue University, LaFayette, Indiana.

W. E. Blowers, Student, Purdue University, LaFayette, Indiana.

M. Aldrich, Student, Purdue University, LaFayette, Indiana.

R. C. Jones, Car Foreman, Terre Haute, Indianapolis & Eastern Traction Co.

Frank White, Motorman, Terre Haute, Indianapolis & Eastern Traction Co.
Elwood Smith, Motorman, Terre Haute, Indianapolis & Eastern Traction Co.
Homer Siegman, Motorman, Terre Haute, Indianapolis & Eastern Traction Co.
——— Collins, Motorman, Terre Haute, Indianapolis & Eastern Traction Co.
R. C. Barker, Conductor, Terre Haute Indianapolis & Eastern Traction Co.

Respectfully submitted,

S. D. HUTCHINS,
H. C. DECAMP,
C. A. BROWN,
G. K. JEFFRIES,
D. D. EWING,
S. W. GREENLAND,
Committee.

SECTION II

Description of Equipment Tested

Construction Features. A brief summary of the main constructional features of the cars tested was presented in Table 1 of Section I. More complete descriptions of these features for the several cars are contained in Tables 6, 7, 8 and 9.

Fig. 5—The Test Track from Pettigrew Siding.

Fig. 6—Car No. 244 and Some of the Observers and Test Crew.

TABLE 6

General Construction Data

Interurban Car No. 61
Owner—T. H. I. & E. Traction Co.
Type—Interurban.
Weight Empty—77400 Lb.
Trucks:
Number—2
Type—Baldwin—Nos. 4197 and 4204
Axle Diameter—6 inches
Wheels:
Diameter—35 19/32 inches
Kind—Steel tired
Weight—690 lb.
Condition of Tread—Worn
Body:
Length Overall—59 ft. 3 in.
Length Dash to Dash—56 ft. 9 in.
Height Rail to Roof—13 ft. 8 in.
Height of Body—10 ft. 0 in.
Width of Body—8 ft. 3 in.
Motors:
Number—4
Type—West. No. 304
Weight—3550 Lb. Each
Gear Ratio—24-63
Controller:
Type—K-36-B
Brakes:
Type—Combined Straight and Automatic Air
Westinghouse Amm
M22—Brake Valve
M2B—Triple Valve
Kind of Shoes—Diamond "S"
Shoe Area in Contact—100 Per Cent (Est.)
Air Reservoir—Two Tanks 16 in. x 45 in.
Air Cylinder—Diameter 14 in. Length 12 in.
Air Compressor—D-2 E G
Compressor Governor—Type J
Sander:
Air

TABLE 7

General Construction Data

City Car No. 244
Owner—Indiana Service Corporation
Type—City
Weight Empty—34,200 Lb.
Trucks:
Number—2
Type—Baldwin No. 9963
Axle Diameter—4 15/16 inches.
Wheels:
Diameter—29 3/4 inches
Kind—Steel tired
Weight—503 lb.
Condition of Tread—Good
Body:
Length Overall—42 ft. 0 in.
Length Dash to Dash—41 ft. 3 in.
Height Rail to Roof—11 ft. 2 in.
Height of Body—8 ft. 9 in.
Width of Body—8 ft. 3 in.
Motors:
Number—4
Type—West. No. 506
Weight—900 lb. Each
Gear Ratio—14-78
Controller:
Type—K-12-A
Brakes:
Type—Straight Air
Kind of Shoes—Cast Iron with Steel Backs and Chilled Ends.
Shoe Area in Contact—80 Per Cent.
Air Reservoir—16 in. by 48 in.
Air Cylinder—Diameter 8 in. Length 12 in.
Compressor—D-16
Brake Valve—PV-3
Governor—S-6-B
Sander:
Air

TABLE 8

General Construction Data

City Car No. 1026
Owner—Indianapolis Street Railway Company.
Type—City
Weight Empty—39,700 lb.
Trucks:

Number	2
Type	C 50 P
Axle Diameter	4 1/2 inches

Wheels:

Diameter	31 1/8 inches
Kind	Cast Steel
Weight	550 lb.
Condition of Tread	Worn

Body:

Length Overall	47 ft. 3 in.
Length Dash to Dash	46 ft. 3 in.
Height Rail to Roof	12 ft. 3 in.
Height of Body	9 ft. 2 in.
Width of Body	8 ft. 6 in.

Motors:

Number	2
Type	West. 310-E-2
Weight	3510 lb. Each
Gear Ratio	15-69

Controller:
Type—K-51-A
Brakes:
Type—Straight Air
Kind of Shoes—Grey Iron with Steel Backs and Chilled Ends
Shoe Area in Contact—100 Per Cent
Air Reservoir—Two Cylinders 16 in. by 33 in.
Air Cylinder—Diameter 10 in., Length 12 in.
Compressor—DH-16
Governor—CD-17
Brake Valve—PV-3
Sander:
Type—Hand

TABLE 9

General Construction Data

Car No. 55
Owner—Northern Indiana Power Co.
Type—City, Birney Safety Car
Weight Empty—15,200 lb.
Trucks:

Number	1
Type	No. 79-E-1
Axle Diameter	3 15/16 inches

Wheels:

Diameter	24 5/8 inches
Kind	Cast Steel
Weight	322 lb.
Condition of Tread	Good

Body:

Length Overall	28 ft. 1 in.
Length Dash to Dash	26 ft. 8 in.
Height Rail to Roof	9 ft. 7 1/2 in.
Height of Body	7 ft. 11 1/4 in.
Width	7 ft. 9 in.

Motors:

Number	2
Type	G. E. 264
Weight	1005 lb. Each
Gear Ratio	13-74

Controller:
Type—K-10-A
Brakes:
Type—Standard Safety Equipment
Kind of Shoes—Cast Iron with Steel Back and Chilled Ends.
Area in Contact—100 Per Cent
Air Reservoir—10 in. by 36 in.
Air Cylinder—Diameter 6 in. Length 12 in.
Compressor—CP-25
Governor—ML-Form A-1, G.E.
Sander:
Type—Air

Car Loadings. The number of persons, including the crew, on the car are shown for each test in Tables 1-A, 1-B, 1-C and 1-D (Appendix). The total loads included, in addition to the weight of the passengers, the weight of the testing equipment

Fig. 7 —City Car No. 1026 on the Side Track Near Pettigrew Substation.

which was estimated at 300 pounds. Two sets of tests were run on Car No. 55. In one set an additional load of 1900 pounds of sand and cement was carried in order to bring the total load up to that obtained in ordinary service with all seats occupied.

Fig. 8—Birney Car No. 55 on the Test Track.

In a second set of tests the load included only those necessary to operate the equipment and the weight of the test equipment, 300 pounds. The live load weights are not exact as they were determined by asking each person how much he weighed. A summary of the car loadings is contained in Table 10. These were the loads used in calculating the percentage braking power discussed in a later paragraph, although, as will be noted from the log sheets, the number of persons on the cars varied somewhat from time to time.

TABLE 10
Car Loadings

Car No.	Live Load Pounds	Dead Load Pounds	Remarks
61	4439	300	All Tests
244	4007	300	All Tests
1026	2558	300	All Tests
55	3046	2200	Load Tests
55	1445	300	Light Load Tests

Brake Rigging. Brake rigging diagrams showing the dimensions of the several levers and shoe pressures, as calculated for a brake cylinder pressure of 50 pounds per sq. in., are shown in Figs. 9, 10, 11 and 12. The dimensions were measured with the levers in place. Owing to worn holes and pivot bolts, some of

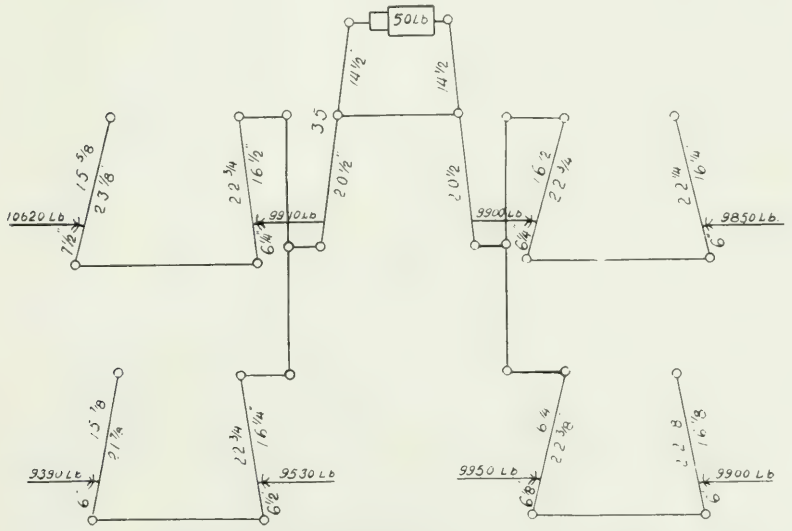


Fig. 9—Brake Rigging Diagram, Interurban Car No. 61.

the measurements were very difficult to make, the dimensions shown being as near accurate as it was possible to measure them. An attempt was made to secure information relative to the lengths of the levers as specified in the original car specifications. To

this end the truck manufacturers and operating companies were communicated with and while the data was not complete in all cases, Table 11 shows in a general way the comparison between specified and actual lever lengths. For the truck levers the measured dimensions shown are the averages for all similar levers.

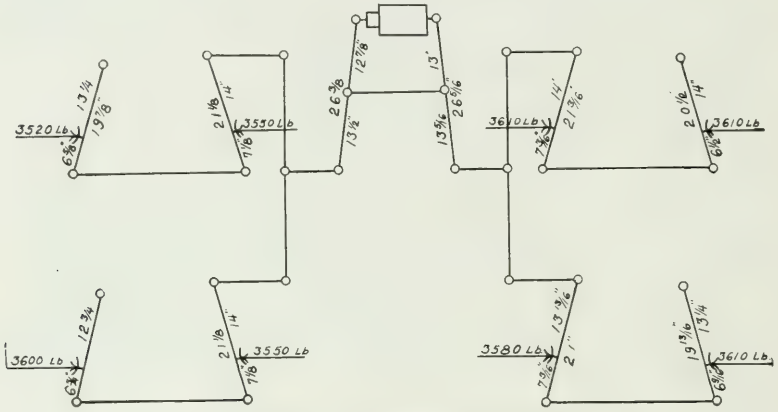


Fig. 10 –Brake Rigging Diagram, City Car No. 244.

In preparing for the test changes were made only on Car No. 61. Calculations showed that this car had a braking power at light load of only 79 per cent. The foundation levers were so changed as to give the car a braking power of approximately 100 per cent at light load. Also a bad leak in the piping between the brake cylinder and the auxiliary reservoir was repaired.

TABLE 11
Comparison of Specification and Measured Brake Lever Lengths in Inches

Car No.	Foundation		Truck	
	Dead Lever	Live Lever	Dead Lever	Live Lever
61				
(a)	------	------	22–6	22–6
(b)	14.5–	14.5–	22.2–	22.2–
	20.5	20.5	6.25	6.25
1026				
(a)	13–	11.2–	19.9–	18.5–
	15	16.8	6.6	9.0
(b)	12.75–	11.5–	20.56–	19.62
	15.37	16,87	7.31	9.69
244				
(a)	13–	13–	19.5–	21–
	13	13	6.5	7
(b)	13–	12.87–	19.75–	21.12–
	13.31	13.5	6.61	7.83
55				
(a)	5.25–	5.25–	----	------
	10.5	10.5	-	------
(b)	4.06–	4.06–	----	12.50
	9.47	9.47	--	15.75

NOTE.—"a" Specification
"b" Measured

Braking Power. Using the measured lengths of the levers as shown in Figures 9, 10, 11 and 12, the braking power of the several cars was computed both in pounds and in per cent for different conditions of loading, as shown in Tables 12, 13, 14 and

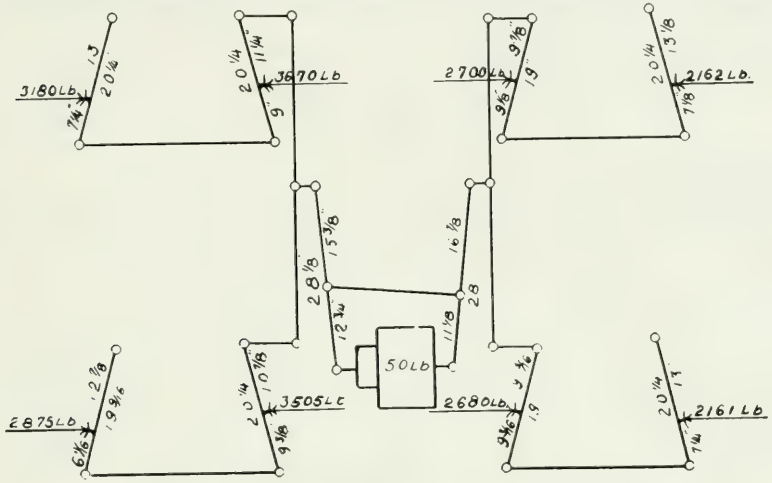


Fig. 11—Brake Rigging Diagram, City Car No. 1026.

15. In each of these tables the braking power for the different conditions is shown for one pound per square inch brake cylinder pressure. To get the braking power at any other pressure the braking power at one pound per square inch pressure may be multiplied by the desired cylinder pressure. In the tables the braking power at 50 pounds per square inch, 60 pounds per square

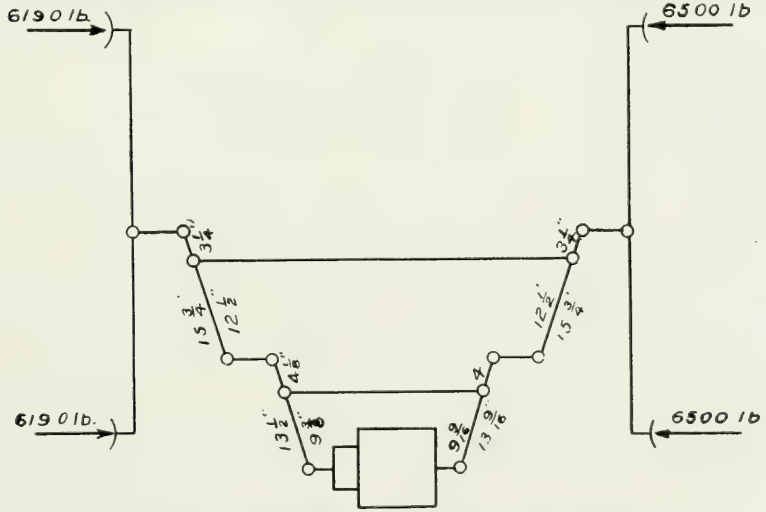


Fig. 12—Brake Rigging Diagram, Birney Car No. 55.

inch cylinder pressure and for the average pressures for the low pressure and high pressure tests have been computed. Low pressure is defined as that pressure corresponding to the lower limit in the range of governor operation while high pressure corresponds to the upper limit of this range. The average pressures used in these tables are those resulting from a study of the trainagraph records (see Appendix, Tables 4-A, 4-B, 4-C and 4-D).

TABLE 12
Interurban Car No. 61
Braking Power Under Different Conditions

B. C. Pressure Lb. per Square Inch	Kind of Braking*	Load Pounds	Total Weight Pounds	Braking Power Pounds	Braking Power Per Cent	Remarks
1.0	A.		77,400	1579	2.045	
50.0	A.		77,400	78850	102.1	
1.0	A.	4739	82,139	1579	1.928	
50.0	A.	4739	82,139	78850	96.0	
60.0	A.	4739	82,139	94740	115.2	
59.6	A.	4739	82,139	94100	114.6	
70.3	S. & A.	4739	82,139	111300	135.5	High Pressure Average
50.0	S. & A.	4739	82,139	78850	96.0	Low Pressure Average
70.0	S.	4739	82,139	111000	135.0	High Pressure
59.5	R.M. + A.	4739	82,139	94000	114.5	

*Note.— A.—Automatic Air, Emergency and Sand.
S. & A.—Straight and Automatic Air, Emergency and Sand.
S.—Straight Air.
R. M. + A.—Reversed Motors Plus Automatic Air, Emergency and Sand.

TABLE 13
City Car No. 244
Braking Power Under Different Conditions

B. C. Pressure Lb. Per Square Inch	Kind of Braking*	Load Pounds	Total Weight Pounds	Braking Power Pounds	Braking Power	Remarks
1.00	E.		34,200	571	1.67	
50.00	E.		34,200	28,550	83.5	
1.00	E.	4307	38,507	571	1.48	
50.00	E.	4307	38,507	28,550	74,2	
60.00	E.	4307	38,507	34,260	89.0	
60.33	E.	4307	38,507	34,450	89.4	High Pressure Average
51.8	E.	4307	38,507	29,600	76.9	Low Pressure Average
63.00	R.M. + E.	4307	38,507	36,000	93.4	

*Note.— E.—Emergency Air and Sand.
R. M. + E.—Reversed Motors Plus Emergency Air and Sand.

TABLE 14
City Car No. 1026
Braking Power Under Different Conditions

B. C. Pressure Lb. Per Square Inch	Kind of Braking*	Load Pounds	Total Weight Pounds	Braking Power Pounds	Braking Power Per Cent	Remarks
1.00	E.		39,700	460	1.16	
50.00	E.		39,700	23,000	58.00	
1.00	E.	2858	42,558	460	1.083	
50.00	E.	2858	42,558	23,000	54.15	
60.00	E.	2858	42,558	27,600	65.00	
62.64	E.	2858	42,558	28,840	67.8	High Pressure Average
53.7	E.	2858	42,558	24,150	58.0	Low Pressure Average
63.3	R.M. + E.	2858	42,558	29,150	68.4	High Pressure Average

*Note. E.—Emergency Air and Sand.
R. M. + E.—Reversed Motors Plus Emergency Air and Sand.

TABLE 15
Birney Car No. 55
Braking Power Under Different Conditions

B. C. Pressure Lb. Per Square Inch	Kind* of Braking	Load Pounds	Total Weight Pounds	Braking Power Pounds	Braking Power Per Cent	Remarks
1.0			15,200	507	3.34	Empty Car
50.0			15,200	25,350	167.0	Empty Car
60.0			15,200	30,450	200.5	Empty Car
1.0		1755	16,955	507	2.99	
50.0		1755	16,955	25,350	149.2	
60.0		1755	16,955	30,450	179.7	
54.5	H. U.	1755	16,955	27,650	163.2	Low Pressure Average
66.8	H. U.	1755	16,955	33,850	199.5	High Pressure Average
57.3	E.	1755	16,955	29,050	171.5	Low Pressure Average
65.3	E.	1755	16,955	33,100	195.5	High Pressure Average
1.0		5546	19,746	507	2.57	
50.0		5546	19,746	25,375	128.1	
60.0		5546	19,746	30,450	154.1	
54.5	H. U.	5546	19,746	27,650	140.0	Low Pressure Average
66.8	H. U.	5546	19,746	33,850	171.5	High Pressure Average
57.3	E.	5546	19,746	29,050	147.3	Low Pressure Average
65.3	E.	5546	19,746	33,100	167.6	High Pressure Average

*Note.—H. U.—Hands up Braking
E. —Hand operation of Brake Valve.

The Test Track. Certain details relative to the test track were presented in Section I but it seems advisable to present here the reasons for its selection. The selection was made because:

(1) The track is approximately level and is part of a long, tangent track.

(2) It is near a substation and siding, thus providing an ample power supply and preventing an excessive loss of time in avoiding the regular traffic.

(3) It is near the end of a line on which a two-hour schedule is maintained, thus permitting long test periods without interrupting traffic.

The track is of standard interurban railway construction with cinder ballast.

In order to minimize as much as possible the effect of variations in track level and the wind resistance, tests were run in both directions. After a series of tests were run in one direction on a car it was run to Crawfordsville and turned and a series of check runs made in the other direction.

SECTION III

Organization, and Arrangement and Details of Testing Equipment

Organization. The organization for each test is listed on the headings of the copies of the test log sheets, Appendix, Tables 1-A, 1-B, 1-C and 1-D. Before starting the tests a schedule of tests was prepared for each car.

The general plan was to run those tests first which were least likely to damage the car. Thus, low speed air brake tests were scheduled first, then the higher speed air brake tests. These were followed by the electrical braking tests. As will be seen from a study of the log sheets a fixed schedule was not followed, the general plan being to run as many tests as possible between interruptions caused by the regular traffic over the road. The tests have been grouped by kinds and in order of speed in the summaries shown in Tables 2, 3, 4 and 5.

Procedure. In starting a test run the motorman notched the controller rapidly. His instructions were to accelerate the car just as if he had a very high schedule speed to maintain. When the speed had reached a value, specified before the run was started, the speedmeter observer raised his hand, the director of tests then touched the man who fired the gun. The report of the gun was the signal for the motorman to make an emergency stop. After the car had come to a standstill, the instrument men marked their graphic charts, the distance was measured and the data recorded. In some cases the brake cylinder piston travel was also measured.

To facilitate clearness and accuracy all test run numbers on Car No. 61 were prefixed with the letter *A*, those on Car No. 244 with *B*, those on Car No. 1026 with *C* and those on Car No. 55 with *D*.

All the tests made were emergency braking tests and no service braking data are included in this bulletin.

Testing Equipment. A list of the principal items of the testing equipment was given in Section I. A more detailed description of this equipment will be presented here.

Chronograph. A cut of this instrument is shown in Figure 13. It consisted of:

(1) A drum, approximately six inches in diameter by 17 1/2 inches long, which held the paper record chart.

(2) A spring motor which drove the drum,

(3) A Seth Thomas clock with electrical contacts which were so arranged as to close twice per second.

(4) A relay and electrical connections,

(5) Two magnet operated pens.

A diagram of the electrical connections is shown in Figure 14. It will be noted that the chronograph clock and battery operated the time pens on the trainagraph and speedmeter. One of the chronograph pens was connected in the circuit with a contact maker which was attached to the end of one of the car axles. This contact maker was adapted from an automobile timer and

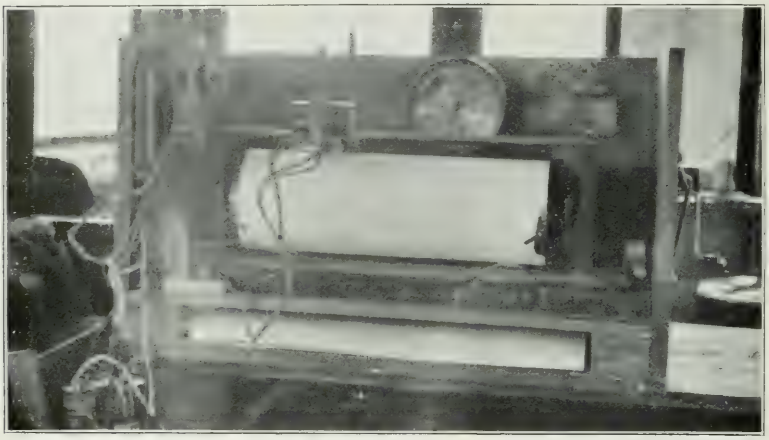


Fig. 13—The Chronograph.

was so arranged that the contact was "made" for one-half of the wheel revolution and "broken" for the other half. The other chronograph pen circuit was arranged with a single pole double throw switch so that it could be connected in series, either with the time circuit, or with a special contact placed on the brake

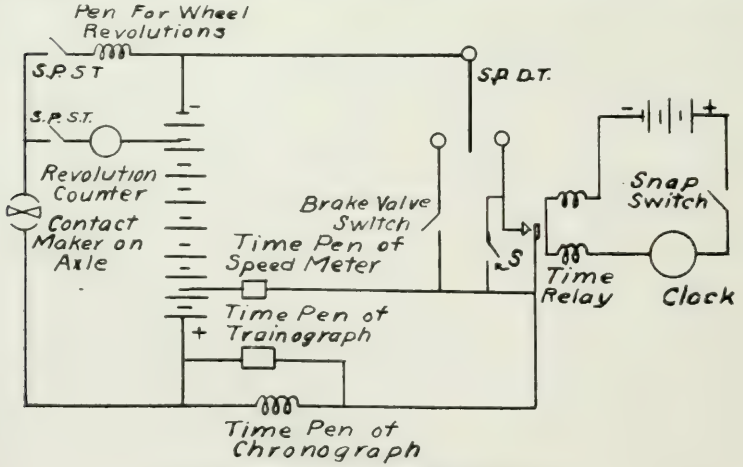


Fig. 14—Diagram of Electrical Connections.

valve. In some of the tests on the Birney Car No. 55 the special contact was placed on the controller so that the removal of the motorman's hand from the controller handle permitted the handle to spring up and make the contact.

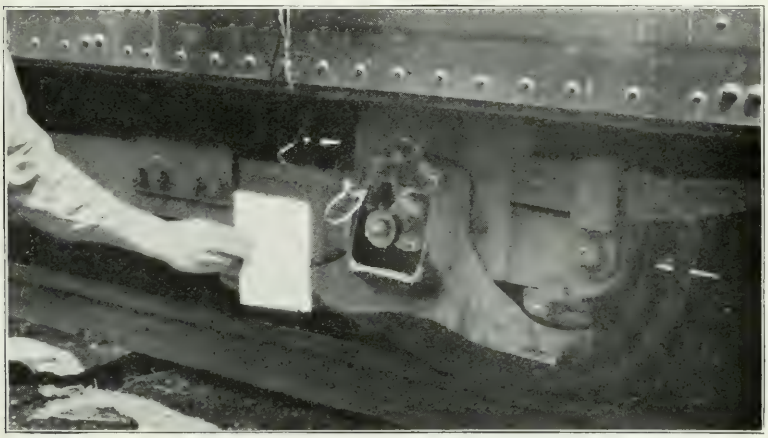


Fig. 15—Electrical Contact Maker Mounted on the End of an Axle.

In the air brake tests the general method of operation was to connect the time pen circuit to the brake valve contact a few seconds before the stop signal was given. When the brake valve was thrown to the emergency position the brake valve contact was broken thus deenergizing the time pen magnet and giving an indication on the chart as shown in Figure 16. Immediately after this indication the chronograph operator threw the single pole double throw switch, thus connecting the pen to the time circuit and giving the half second indications shown on the chart.

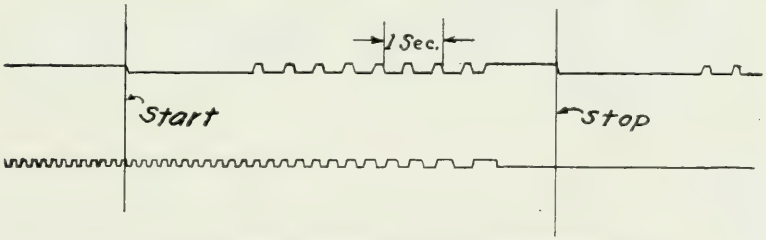


Fig. 16—A Typical Chronograph Chart, Run Number D-39.

Just before the car came to a stop the chronograph operator closed the key switch S, short-circuiting the time relay contacts. At the instant the car stopped the operator opened the double throw single pole switch giving the stop indication. The switch S was then opened and the double throw single pole switch closed thus starting the time indications again.

In the electric braking tests the operator made an indication on the chart, similar to that made in the air brake tests by the brake valve contact, by manipulation of the double pole single throw switch.

The lower pen record is that of wheel revolutions, each offset in the curve representing a revolution. The slowing down of the car is shown by the longer offsets.

As the chronograph chart was driven at constant speed both the time interval of stopping and the speed at various times could be calculated from the chart records. The time intervals and speeds so determined were considered more accurate than those determined by other methods and are used exclusively in the analysis of the test data contained in succeeding sections of this bulletin.

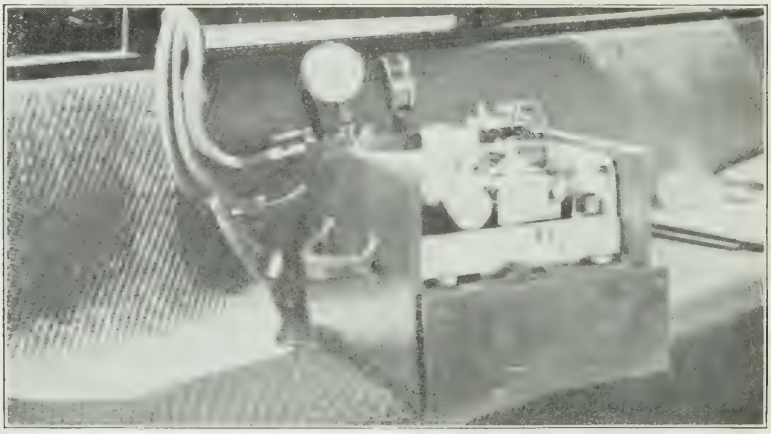


Fig. 17—The Trainagraph Set Up in Car No. 1026

Trainagraph. A cut of the trainagraph is shown in Figure 17. This is an instrument built by the American Steam Gauge and Valve Manufacturing Company and is equipped with three graphic recording pressure indicators and a time pen. The chart is driven by a constant speed spring motor. In these tests the time pen was energized from the chronograph clock, thus synchronizing the two instruments. Except in the tests on Car No. 55, only two of the pressure indicators were used, one measuring brake cylinder pressures and the other the brake pipe or main reservoir pressure, depending on the type of brake. The indicators were connected to the air piping by means of small diameter high pressure air hose. The instrument was also provided with precision pressure gauges. Readings of these gauges are recorded in Tables 1-A, 1-B, 1-C and 1-D, Appendix. Typical pressure diagrams, enlarged, are shown in Figures 30, 43, 57, and 70.

TABLE 16
Magneto and Speedometer Data

Car No.	61	244	1026	55
Car Wheel Diameter	35 19/32 in.	29 3/4 in.	31 1/8 in.	24 5/8 in.
Axle Diameter	6 in.	4 15/16 in.	4 1/2 in.	3 15/16 in.
Magneto Pulley Diameter	1 1/2 in.	1 1/2 in.	1 1/16 in.	1 1/16 in.
Adjusting Resistance Ohms	21.7	19.8	14.8	2.05
Magneto Voltage Per 1000 R.P.M. of Armature	3.906	3.906	3.906	3.906
Calculated Full Scale Reading of Speedmeter in M. P. H.	80.00	80.00	50.00	50.00

NOTE.—Resistance of Voltmeter Coil equals 120.3 ohms.

Two sets of tests were run on the cars equipped with straight air brakes. In one set the main reservoir pressure corresponded to the upper limit of the air pressure governor range and in the other set to the lower limit of the range. A bleeding cock in the hose line connected to the main reservoir enabled the trainagraph operators to reduce the pressure to the proper value for each test.

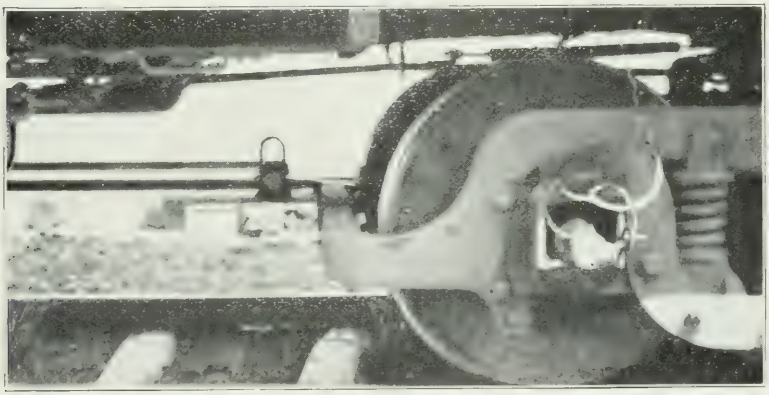


Fig. 18—The Magneto and Contact Maker Attached to Car No. 1026.

Speedmeter. To facilitate the determination of speed while the test was in progress a graphic recording Esterline voltmeter was used in connection with a direct current magneto. In such a magneto the generated voltage is directly proportional to the speed of the magneto armature. The magneto was belted to the driving axle by means of a flat belt and an adjustable resistance was inserted in series with the voltmeter so as to permit adjusting the range of the instrument to fit the different conditions of wheel and axle diameter. The principal data for the speedmeter equipment are shown in Table 16.

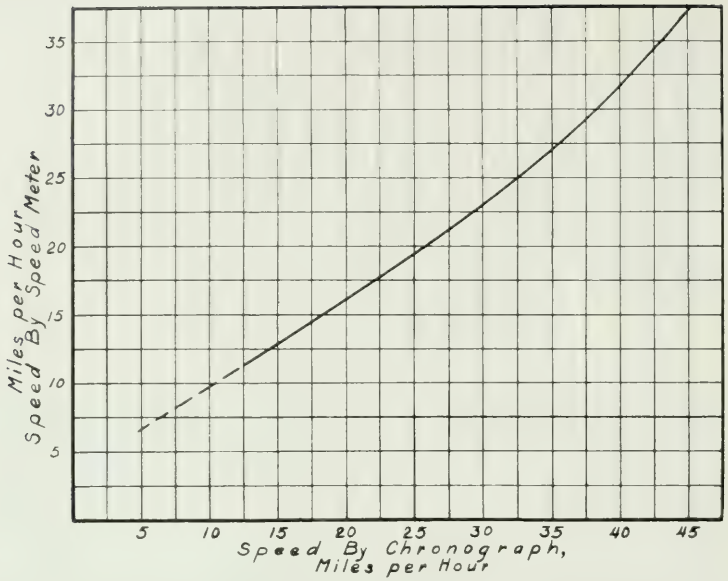


Fig. 19—Speedmeter Calibration Curve for Car No. 61

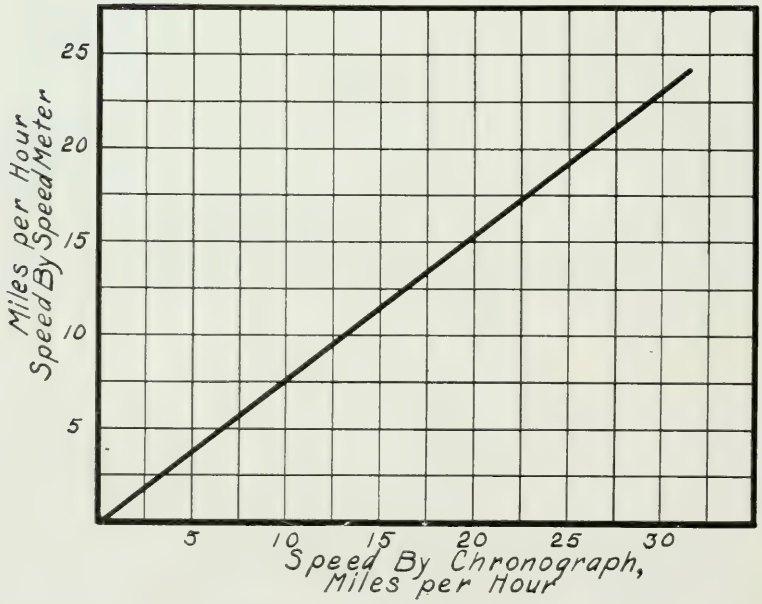


Fig. 20—Speedmeter Calibration Curve for Car No. 244.

Previous tests, in which the magneto was chain driven, had shown this to be a quite accurate method of measuring speed. In these tests the belt drive was selected because of the facility with which the magneto could be connected to the driving axle. Owing to the effect of belt thickness on the effective pulley ratios and belt slippage the speedmeter readings taken in these tests are only approximate. In order to make them of value, calibration curves of the speedmeter for each car were drawn and are shown in Figures 19, 20, 21 and 22.

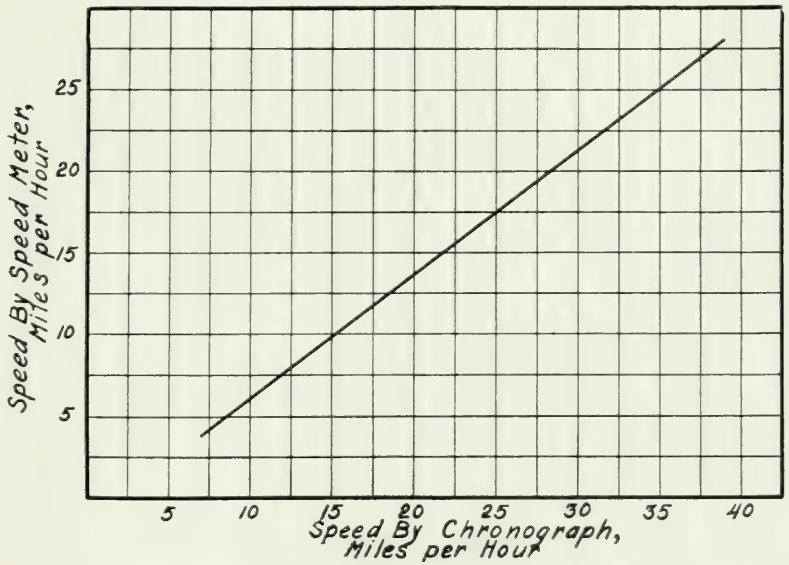


Fig. 21—Speedmeter Calibration Curve for Car No. 1026.

The speedmeter was also equipped with a time pen which was actuated from the chronograph time circuit thus showing accurately the braking and stop indications on the speedmeter charts.

Except on Car No. 1026 it was necessary to connect the magneto and contact maker to driven axles. In all cases the magneto and contact maker were connected to the same axle.

Revolution Counter. As a check on the distance traveled over in bringing the car to a stop, an electrically operated car wheel revolution counter was used. The connections to this counter are shown in Figure 14, the axle contact maker used for the chronograph being used for this instrument also. The circuit to the counter was closed by the observer at the instant the stop signal was given. The number of revolutions counted, therefore, were those occurring from the instant the stop signal was given until the car was brought to a standstill. The observer who operated the counter also measured, with a stop watch, the time

necessary to bring the car to a stop. Similar time readings were taken by other observers. Both time and revolution counter data are recorded in Tables 1-A, 1-B, 1-C and 1-D.

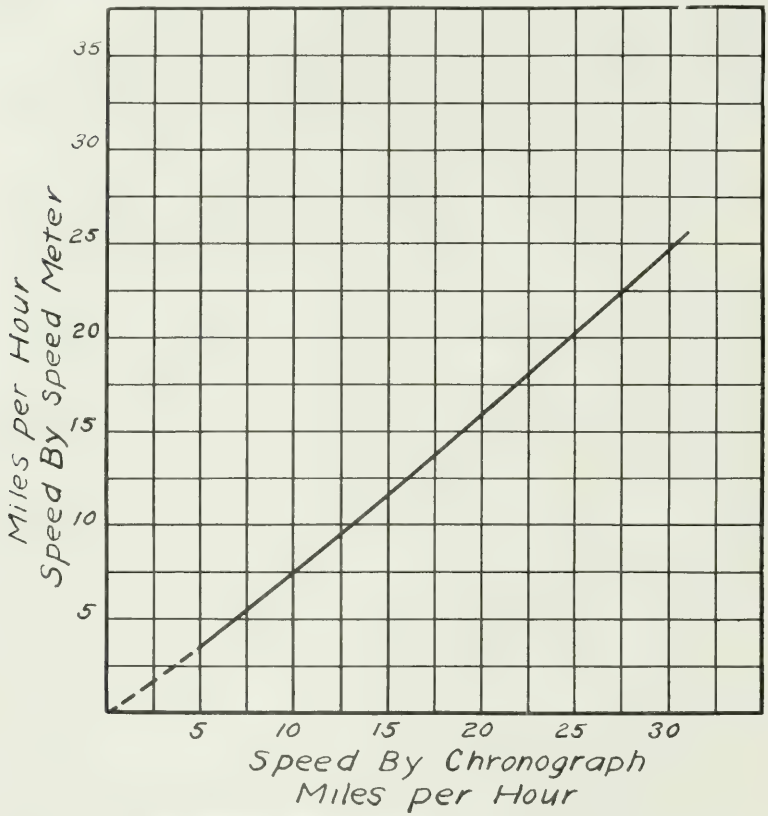


Fig. 22 —Speedmeter Calibration Curve for Car No. 55.

The Stop Signal and the Measurement of Distances. As decribed in Section I a shotgun was used to give the stop signal and mark the point, along the track, where the signal was given. In the first few tests the order to fire was given verbally but as it was found that the motorman was anticipating the report of the gun, the order, in all of the latter tests, was given by the director of the tests simply touching the man with the gun. This plan proved very satisfactory. The distance covered in bringing the car to a stop was measured with a surveyor's 100 foot steel tape. The measurement was made between the shot mark in the track and the point at the car where the line of sight along the gun barrel intersected the track.

SECTION IV

Theoretical Considerations

Before discussing the results of the tests it is of interest to review the theoretical phases of the problem. These will be briefly touched upon in the following paragraphs.

Braking Force. The force necessary to stop a car with a given rate of braking or retardation is given by the familiar relation,

$$f = ma$$

where f is the force in pounds, m is the mass and a is the rate of retardation expressed in feet per second per second. In railway work the units of ton, and mile per hour per second are more familiar and convenient. So expressed the retarding force,

$$F = \frac{W \times 2000 \times 5280\ A}{32.2 \quad 3600} = 91.1\ WA.$$

Where F is in pounds, W is the weight in tons and A is the braking or accelerating rate in miles per hour per second.

The meaning of this formula is that it requires a force of 91.1 pounds for each ton of car weight, directed against the motion of the car, to produce a retarding rate of one mile per hour per second.

Rotative Effect of Wheels and Armatures. In the equation of the preceding paragraph the whole weight of the car was considered as simply moving forward. As a matter of fact the wheels and motor armatures are revolving, and therefore have considerable "fly wheel" effect. The additional braking force to take care of this "fly wheel" effect may be properly computed by adding a certain "equivalent" weight to the car and neglecting the "fly wheel" action. It can be shown that for the wheels this equivalent weight in tons is, $N_w W_w \left(\frac{K_w}{r}\right)^2$, and for the armatures, $N_a W_a \left(\frac{K_a G}{r}\right)^2$, In these expressions:

N_w = Number of pairs of wheels
W_w = Weight of one pair of wheels in tons
K_w = Radius of gyration of wheels, in feet
r = Radius of wheels in feet
N_a = Number of armatures
W_a = Weight of each armature in tons
K_a = Radius of gyration of the armature in feet
G = Gear ratio—teeth in gear divided by teeth in pinion.

If the wheels and armatures be considered as cylinders their radii of gyration can be calculated by dividing their radii in feet by the square root of 2, or 1.414.

The rotative effect equivalent weights have been computed for the cars tested and are shown in Table 17. In Table 18 this equivalent weight has been added to the car weights while in Table 19 the braking power, in per cent, has been computed for brake cylinder pressures of 50 and 60 pounds per square inch. The braking powers in this table may be compared with those in Tables 12, 13, 14 and 15, in making a study of the effect of the rotational inertia of the wheels and armatures on braking power.

TABLE 17
Rotative Effect of Wheels and Armature
Expressed in Tons of Car Weight

Car No.	61	1026	244	55
Wheel Weight, Pounds	690	550	503	322
Wheel Diameter, Inches	35 19/32	31 1 8	29 3 4	24 5/8
Armature Weight, Pounds	830	830	210	205
Armature Diameter, Inches	14.5	14.5	9	8.75
Gear Ratio	24-63	15-69	14-78	13-74
Equivalent Wt. of Wheels, Tons	1.39	1.11	1.013	.32
Equivalent Wt. of Armature, Tons	.9375	1.90	.602	.454

TABLE 18
Total Effective Weight of Cars When the Effect of the Rotation of Wheels and Armatures is Included

Item	Car No. 61	Car No. 244	Car No. 1026	Car No. 55	Remarks
Weight Empty (Tons)	38.70	17.10	19.85	7.60	
Equivalent Weight Due to Rotative Effect, Tons	2.33	1.62	3.00	.77	
Total	41.03	18.72	22.85	8.37	
Load	2.37	2.15	1.43	.88	Light
				2.77	Heavy
Total	43.40	20.87	24.28	9.25	Light
				11.14	Heavy
Total Weight, Rotative Effect not Included	41.07	19.25	21.28	8.48	Light
				10.37	Heavy

TABLE 19
Braking Power in Per Cent, Rotative Effect of Wheels and Armature Considered

Pounds Per Square Inch B. C. Pressure	Car No.	Load Pounds	Total Equivalent Weight Lb.	Braking Power Pounds	Braking Power Per Cent
1	61	----	82,060	1,579	1.913
50	61	----	82,060	78,850	95.7
60	61	----	82,060	94,740	114.8
1	61	4740	86,800	1,579	1.81
50	61	4740	86,800	78,850	90.5
60	61	4740	86,800	94,740	108.5
1	244	----	37,400	571	1.528
50	244	----	37,400	28,550	76.4
60	244	----	37,400	34,260	91.6
1	244	4307	41,730	571	1.37
50	244	4307	41,730	28,550	68.5
60	244	4307	41,730	34,260	82.2
1	1026	----	45,700	460	1.005
50	1026	----	45,700	23,000	50.25
60	1026	----	45,700	27,600	60.3
1	1026	2860	48,560	460	.947
50	1026	2860	48,560	23,000	47.35
60	1026	2860	48,560	27,600	56.80
1	55	----	16,740	507	3.03
50	55	----	16,740	25,350	151.5
60	55	----	16,740	30,450	181.8
1	55	1755	18,500	507	2.74
50	55	1755	18,500	25,350	137.0
60	55	1755	18,500	30,450	164.4
1	55	5546	22,280	507	2.27
50	55	5546	22,280	25,350	113.5
60	55	5546	22,280	30,450	136.2

Stopping Time. When a car is being stopped at a uniform rate of braking the time necessary to make the stop is,

$$t = \frac{\text{Initial Speed}}{\text{Braking Rate}},$$ where t is the time in seconds.

To illustrate, if the braking rate is 2 miles per hour per second and the initial speed is 20 miles per hour, the time required will be 20/2 of 10 seconds. Conversely if the initial speed be divided by the stopping time the braking rate will be determined. The average braking rates listed in Tables 2, 3, 4 and 5 were calculated in this way. Theoretical stopping times, so calculated, for different braking rates are shown in Fig. 23.

Stopping Distance. The distance traversed by a car in making a stop at a uniform braking rate may be calculated.

$$D = V \times t \times .734,$$

where D is the distance in feet,

V, the initial speed in miles per hour

and t, is the stopping time in seconds.

This rule is the equivalent of multiplying the average speed during the stop, in miles per hour, by the stopping time in seconds and that product by 1.467, a conversion factor used in reducing miles per hour to feet per second. The theoretical stopping distances for several uniform braking rates are shown in Fig. 24.

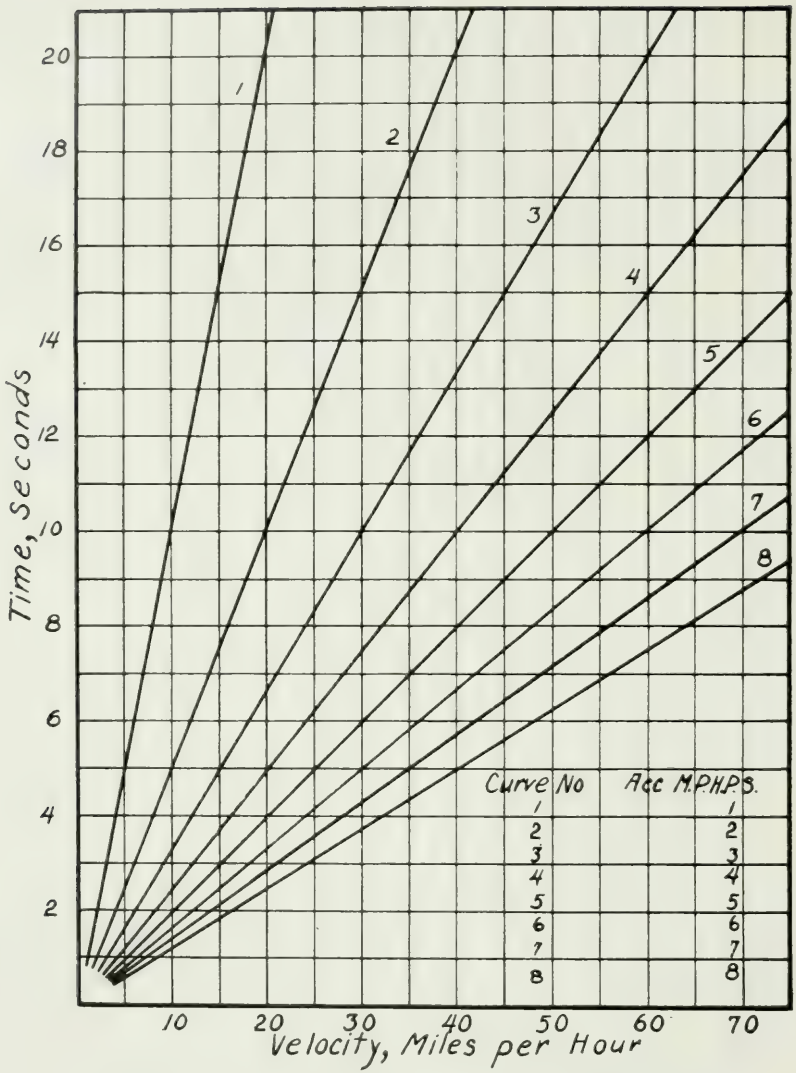


Fig. 23—Theoretical Stopping Times for Different Braking Rates.

Train Resistance. While stopping, the train resistance of the car or train assists the action of the brakes. The train resistance of a car may be determined by making a coasting test on level track, the train resistance in pounds per ton,

$$R = \frac{66.8\ (V_1^2 - V_2^2)}{D}$$

where V_1 is any initial speed,
V_2 any final speed,

and D_2 the distance traversed while the speed was being reduced from V_1 to V_2.

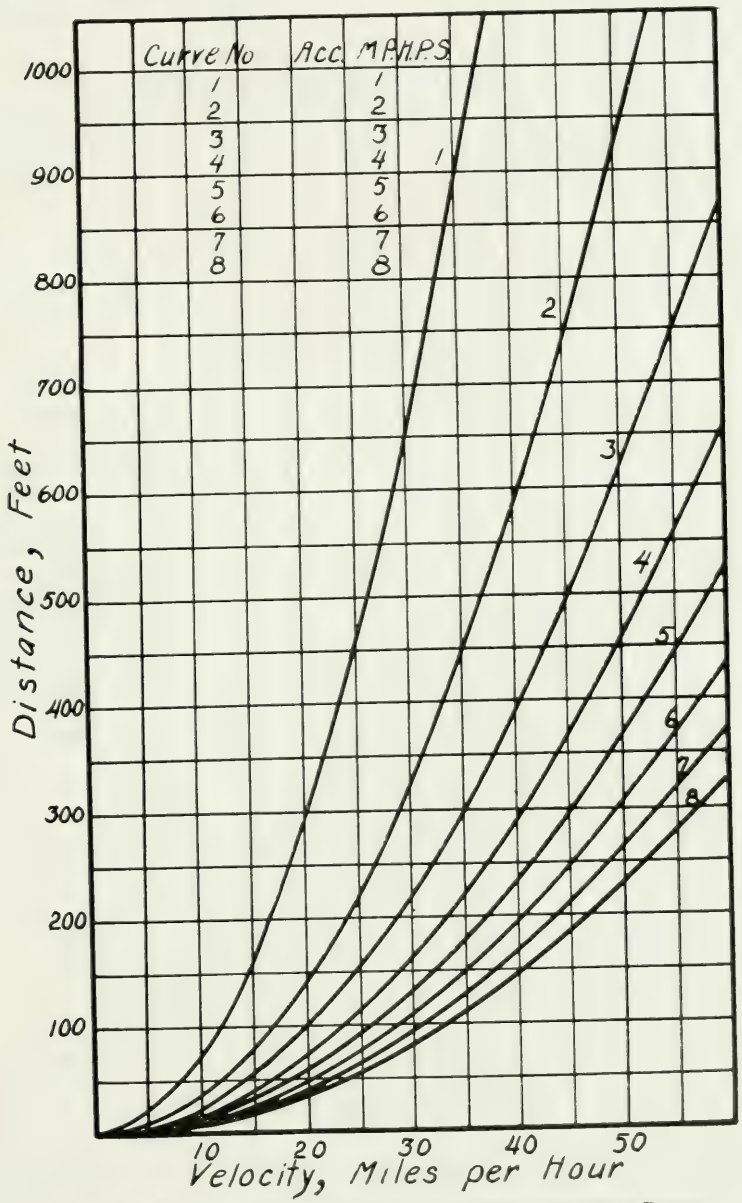


Fig. 24—Theoretical Stopping Distances for Different Braking Rates.

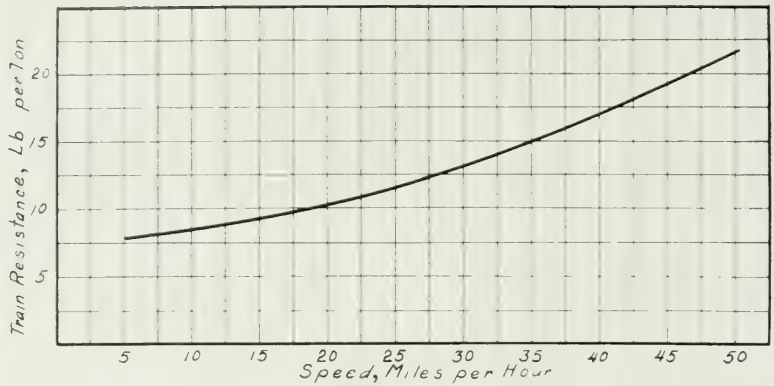


Fig. 25—Train Resistance Curve for Car No. 61.

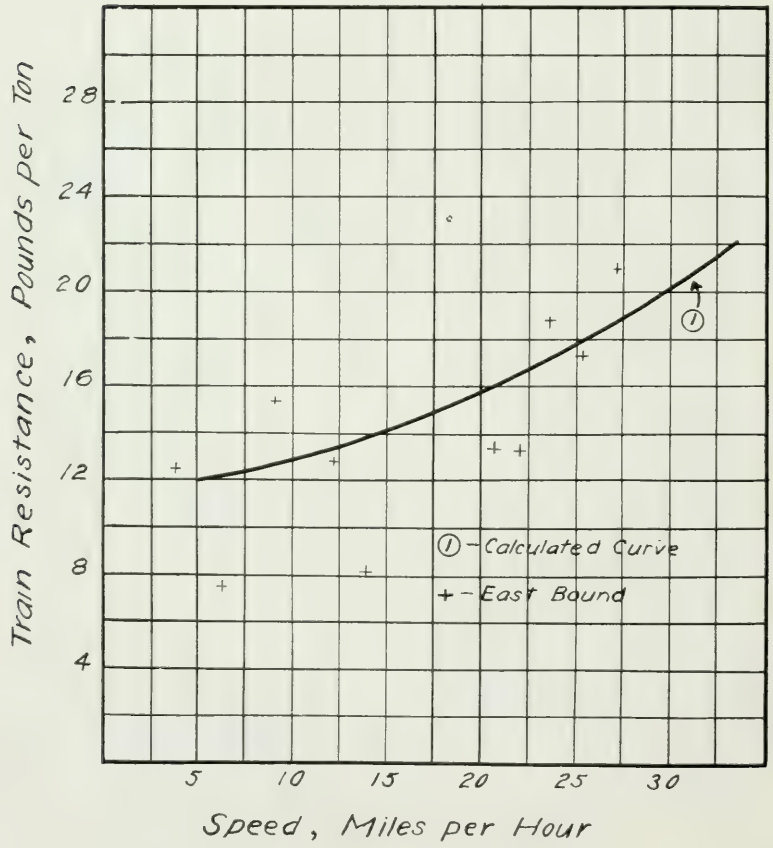


Fig. 26—Train Resistance Curve for Car No. 244.

A great many empirical train resistance formulas have been derived from test data. One by Armstrong is,

$$R = \frac{50}{\sqrt{W}} + 0.03\ V + \frac{0.002 V^2 a}{W}$$

where R = Train resistance in pounds per ton,
W = Weight of the car in tons,
V = Speed of the car in miles per hour,
a = Head end area of the car in square feet.

The train resistance of Car No. 61 calculated by this formula is as in Fig. 25.

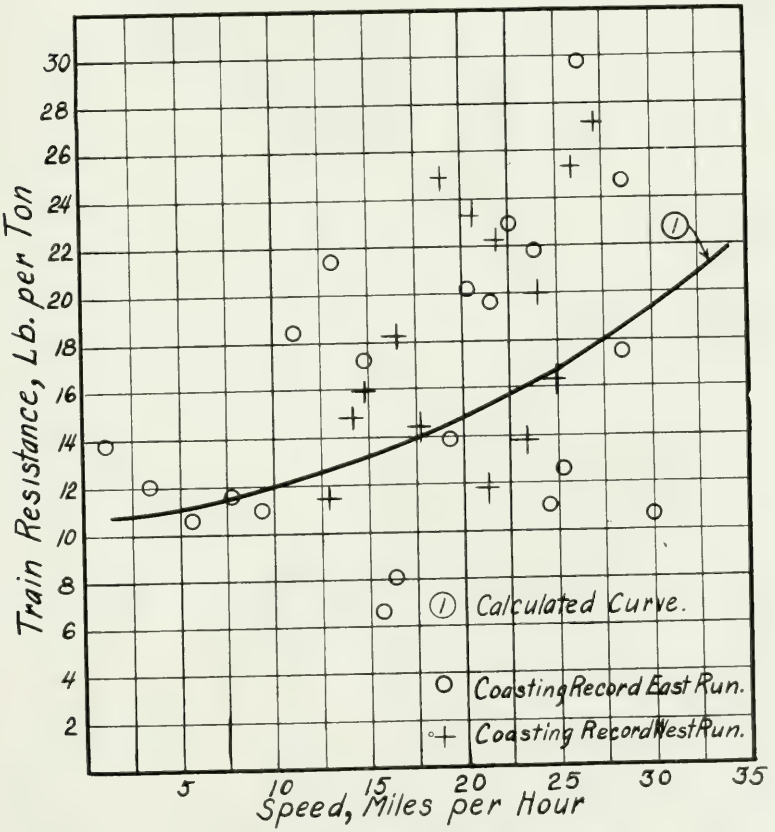


Fig. 27—Train Resistance Curve for Car No. 1026.

Coasting tests were run on the other cars and the train resistance calculated from these tests are shown by the points plotted in Fig. 26, 27 and 28. The curves shown in these figures were plotted from Armstrong's formula. Slight undulations in the track and other variables cause the points to be scattered, but

they are not more scattered than those usually obtained in train resistance tests.

The train resistance, while coasting, may also be calculated by determining the rate of retardation in miles per hour per second and then multiplying this rate by 91.1. The product will be the total train resistance for the speed for which the retardation rate was determined.

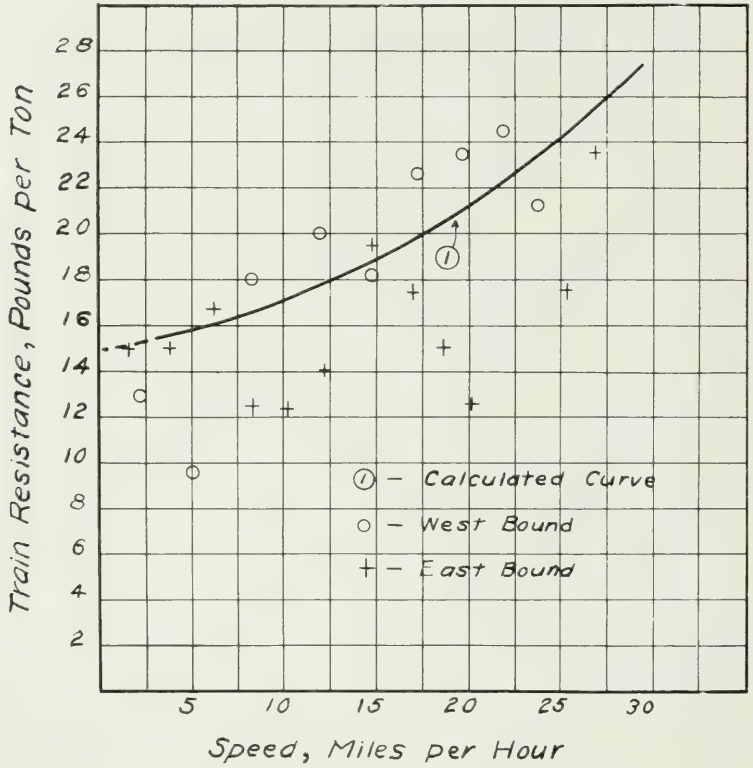


Fig. 28—Train Resistance Curve for Car No. 55.

Brake Rigging Efficiency. As already explained the total retarding force acting on a car may be determined by multiplying the weight of the car in tons by the rate of retardation in miles per hour per second and this product by 91.1. If from this force the train resistance be subtracted there will remain the retarding force produced by the brakes. The brake rigging efficiency then will be,

$$\text{Efficiency} = \frac{\text{Braking force}}{\text{Braking Power} \times \text{Coefficient of Shoe Friction.}}$$

As it is difficult to determine the coefficient of shoe friction with accuracy, the product of this coefficient and the brake rig-

ging efficiency are often used in comparing the efficacy of braking systems. In such comparisons the rate of retardation at a given speed is determined from the speed-time curve which in turn is secured either from the record of a graphic recording instrument or is calculated from a chronograph record.

Maximum Braking Force. Quite apart from such limitations as the heating of wheel rims and brake shoes may impose, the maximum retarding force which may be used in stopping a car is also limited by the adhesion of the wheels to the rails. Thus the weight of the car multiplied by the coefficient of adhesion gives the maximum retarding force. This retarding force less the train resistance gives the braking force, and the braking force divided by the product of brake rigging efficiency and the coefficient of shoe friction gives the required braking power to give maximum retardation. For example, if with dry rail and sand the adhesion reached the high value of 40 per cent the retarding force per ton of car weight would be 0.40×2000 pounds or 800 pounds. Such a force would produce a braking rate of $\frac{800}{91.1}$, or 8.78 miles per hour per second. The braking power required per ton of car weight would be,

$$\frac{800 \text{ lb. Minus the Train Resistance}}{\text{Brake Rigging Efficiency} \times \text{Coefficient of Shoe Friction}}$$

SECTION V

Discussion of Test Results, Car No. 61

In analyzing the test data a large number of tables were compiled and curves drawn. The more important portions of some of the tables are reproduced in the appendix, while in this and the following three sections a number of the curves are reproduced and discussed. As the cars are of different type the discussions of test data are taken up separately, this section being devoted to a discussion of the results obtained in the tests on the interurban car, No. 61.

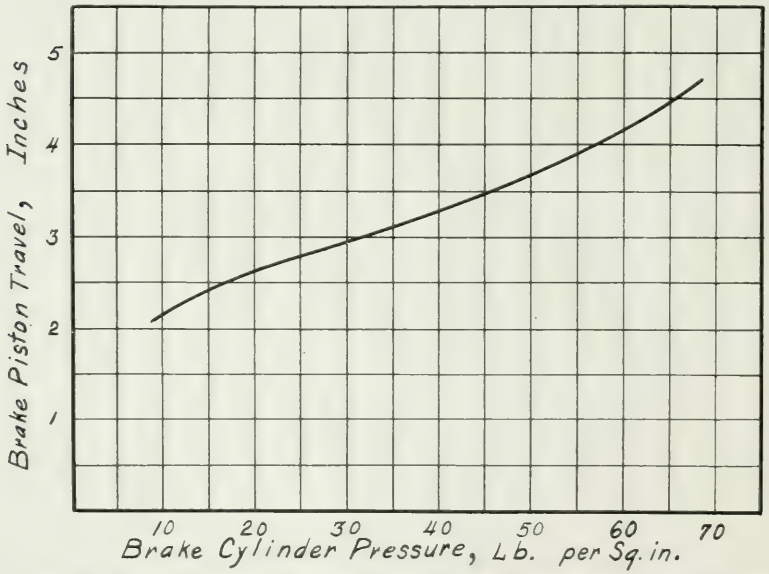


Fig. 29 –Relation Between Standing Piston Travel and Brake Cylinder Pressure, Car No. 61.

Piston Travel. Just before the running tests were started a standing test of piston travel was made. The brakes were operated as straight air brakes, the pressure being increased gradually and the piston travel read at 10 pounds per square inch pressure increments. The results are shown graphically in Fig. 29. It will be noted that the travel at 50 pounds per square inch pressure is 3.7 inches. This car was equipped for the test with a running travel indicator and this indicator showed a running travel of 4 3/4 inches at 49 pounds per square inch brake cylinder pressure. (See Table 1-A, Appendix, Run No. A-29.)

The difference between running and standing travel was therefore approximately one inch. For these brakes the manufacturer recommends that for a 5 inch running travel the standing travel should be adjusted to 4 inches.

Trainagraph Records. A typical record for Car No. 61 enlarged, is reproduced in Fig. 30. This is the record for test No. A-4. It will be noted that there is variation in the brake cylinder pressure just before the stop. An analysis of the relation of the time interval elapsing from the operation of the brake valve to this point of pressure variation, to that obtaining to the actual stop point is contained in Table 11-A, Appendix. The maximum variation of the pressure is also shown in the table. Apparently the cause of the variation was the readjustment of truck parts and brake levers at the lurch of the car that just preceded the actual standstill.

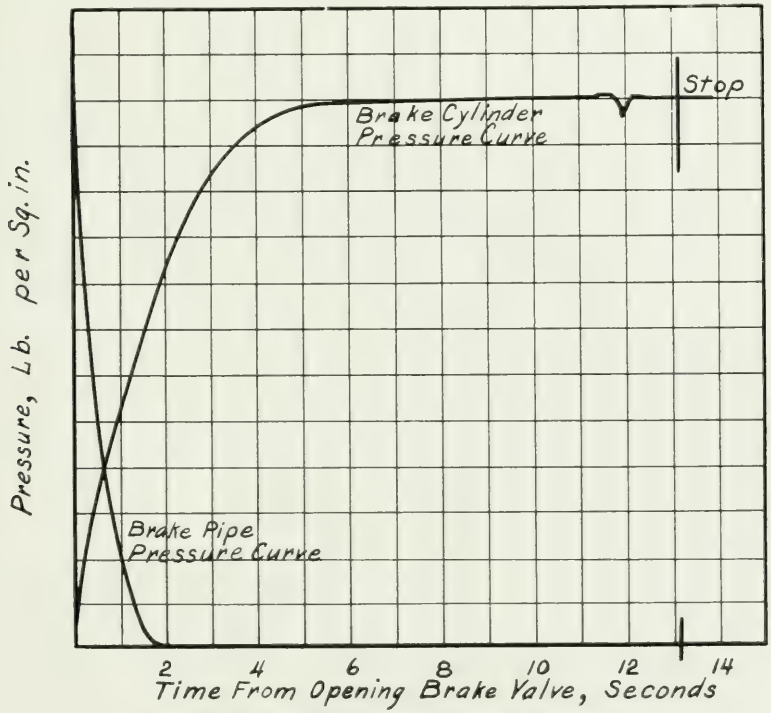


Fig. 30—A Typical Trainagraph Record, Car No. 61.

The curves show that it takes an appreciable time for the pressure in the brake cylinder to reach its full value. Also there is a decided knee in brake cylinder pressure curve before the maximum value of pressure is reached. An analysis of the time elements involved is contained in Table 5-A (Appendix). For automatic air it took about 3 1/2 seconds for the brake cylinder

pressure to reach approximately full value. The length of pipe, number of elbows and other fittings between the auxiliary reservoir and brake cylinder have considerable to do with the magnitude of this time element. There were a number of elbows in this piping on Car No. 61.

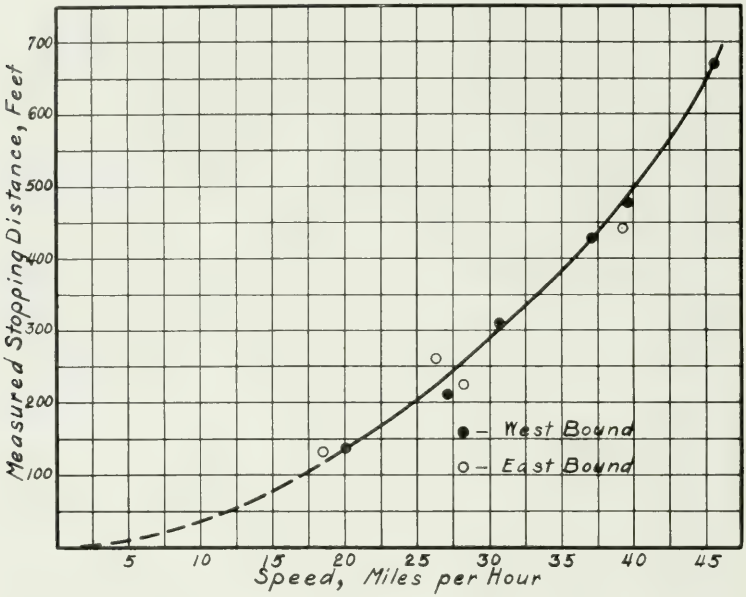


Fig. 31—Automatic Emergency Air Brake Tests, Car No. 61. Relation Between Initial Speed and Distance.

Stopping Distances.—The relation between the distance covered in bringing the car to a stop with automatic air and the initial speed is shown in Fig. 31. Both east bound and west points were plotted. The curve was drawn for the west bound points but seems to fit the east bound points very well. The upper point on this curve is for Run No. A-6, the speed being 45.3 miles per hour and the stopping distance 672.6 ft. (See Table 2.) The mean braking rate is 2.74 m.p.h.p.s. Had the car been braked uniformly at this rate from the instant of the start signal the theoretical stopping distance would have been 553 ft. The discrepancy is due largely to the time it took to get the brakes set after the stop signal was given.

Similarly, the actual initial speed and stopping distance for Run No. A-1 are 20 m.p.h. and 137 feet respectively. The theoretical distance is 95.4 ft.

In order to compare automatic with combined straight and automatic braking the curve in Fig. 31 has been redrawn in Fig. 32, and the curve for the combined system plotted on the same sheet.

In the summary curve Fig. 1, the curve of Fig. 31 has been drawn as a reference line and the points for the various electrical tests plotted on the same sheet. While some of the points for the reversed motors braking tests are below the curve in Fig. 1

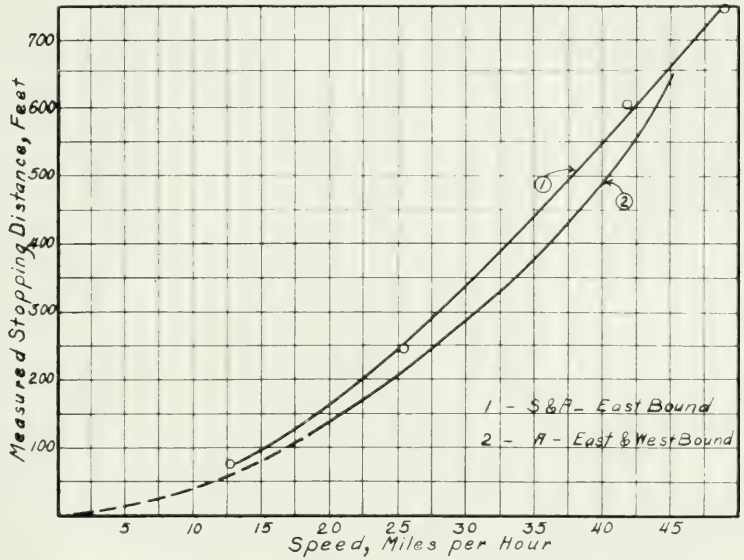


Fig. 32 –Comparison of Automatic, and Straight and Automatic Emergency Air Braking, Car No. 61.

they are not farther below than are some of the points in Fig. 31. From the standpoint of making a stop in a short distance with this car there seems to be little choice between automatic air. reversed motors and reversed motors and automatic air, with track conditions as they existed at the time of these tests. With slippery tracks the advantage would be with the automatic air as with all of the electrical methods there was considerable wheel

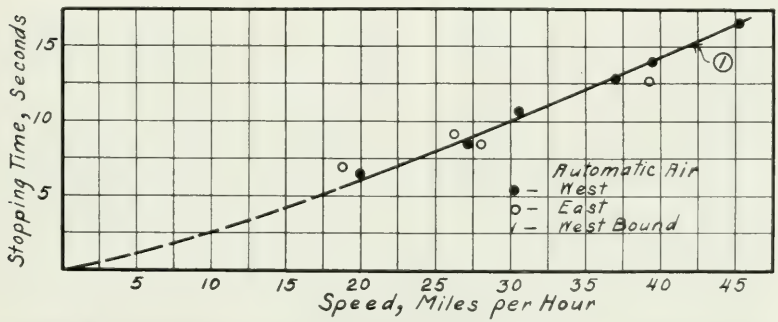


Fig. 33—Automatic Emergency Air Brake Tests on Car No. 61, Relation Between Initial Speed and Time.

slippage (See Fig. 40, 41 and 42). The risk of equipment breakage is very much greater with the electrical methods.

Stopping Time. While from an operating standpoint the time required to bring a car to a full stop in an emergency is not as important as the distance an analysis of the time element has been made in Fig. 33, 34 and 35. In a general way this analysis was made similar to the one on distance as shown in Fig. 1, 31 and 32. The conclusions from the curves are practically the same as far as method of braking is concerned.

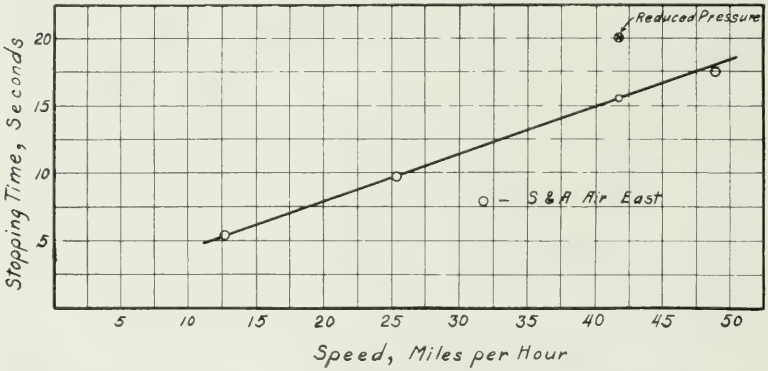


Fig. 34—Relation Between Time and Initial Speed, Combined Straight and Automatic Braking, Car No. 61.

In all of these curves the time used was that determined from the chonograph records. As will be seen from the log sheet, Table 1-A, Appendix, time was also measured with a stop watch, in most tests by more than one observer. A comparison of the individual observations with the stop watches with the time as determined from the chronograph, Table 2-A, Appendix, leads to the conclusion that the motorman threw his air brake lever

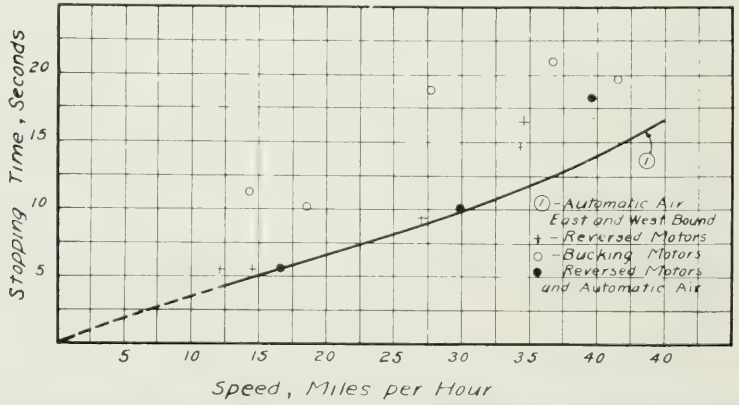


Fig. 35—Relation Between Time and Initial Speed, Car No. 61, for the Various Methods of Braking.

as quickly as the observers were able to press the starting buttons on their stop watches. A comparison of stopping time as determined by several methods is also set forth in Table 10-A, Appendix.

Comparison of Distance Measurements. As was noted in Section II: (1) The actual distance covered in the time from the report of the gun to the standstill position of the car was measured with a tape. (2) The number of wheel revolutions was recorded on a counter whose circuit was closed by an ob-

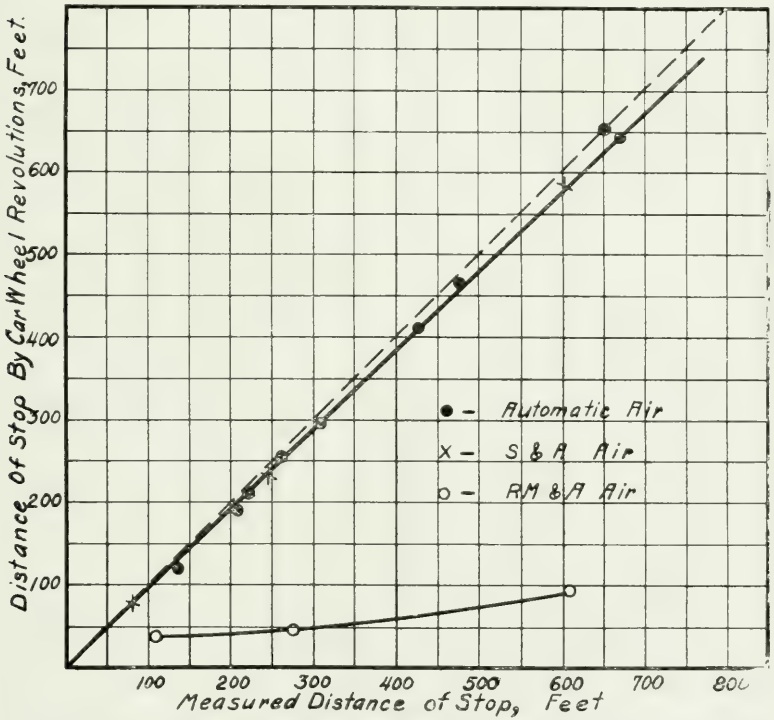


Fig. 36—A Comparison of the Stopping Distance as Determined by Two Methods. Car No. 61.

server upon hearing the report of the gun. (3) The number of revolutions from the operation of the brake valve contact to the stop was recorded on the chronograph record. As the circumference of the wheel to which the revolution counter contact was connected was 9.31 ft., the distance was measured by three methods. The time elements involved were somewhat different however, and wheel slippage would affect the accuracy of the last two methods. An analysis of the results obtained by the three methods is shown in Table 9-A, Appendix. The data, in part, have also been plotted in Fig. 36. The dashed line indicates the

graph that would have been obtained had the distance as measured by wheel revolutions on the chronograph tallied with the measured distance. The full line is drawn through the points and represents the distance measured by the chronograph. As will appear later it is reasonable to believe that the discrepancy is chargeable to the time element of the motorman in operating the brake valve and in the case of the air brake tests to possibly a very small amount of wheel slippage. With combined air and reversed motors the wheels slipped practically from the instant reversed power was applied. With reversed motors alone or with bucking motors the wheels were quite as likely to spin backwards as they were to roll forward or slide. (See also Fig. 39, 40, 41 and 42.)

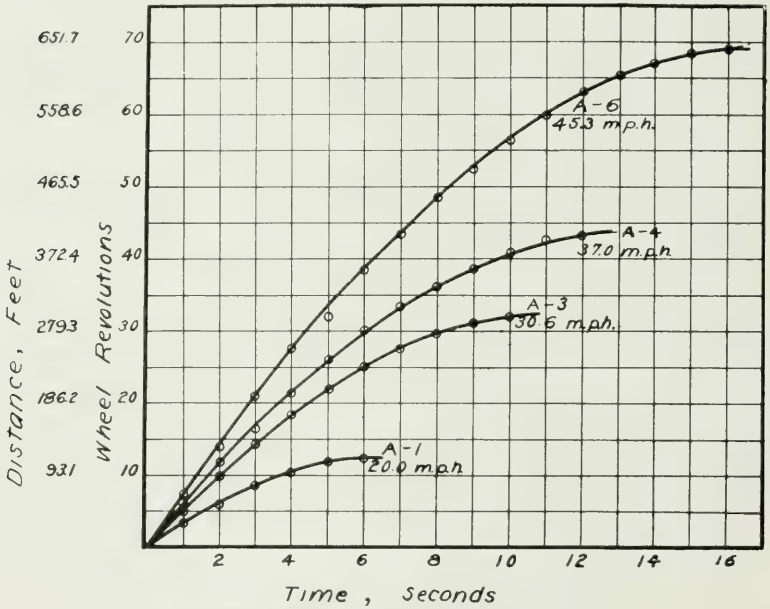


Fig. 37 Typical Distance—Time Curves, Car No. 61.

Distance—Time Curves. Typical distance time curves for several runs of Car No. 61 are shown in Figure 37. The wheel revolutions up to the end of the first, second, third, etc., seconds were take from the chronograph records which were complete and tabulated in Table 3-A, Appendix. The data for Fig. 37 were taken from this table. From these curves and the table it is possible to determine the distance traveled up to the end of any specified number of seconds after the operation of the brake valve contact.

Analysis of the Distance—Time Curve. The curve for Run No. A-6 in Fig. 37 has been redrawn in Fig. 38 The speed

and braking rate curves are derived from the distance time curve. To determine a point on the speed-time curve, the distance covered between two specified instants of time is divided by the time interval between the two instants. The quotient is the mean speed in feet per second. The speed in miles per hour is determined by dividing the speed in feet per second by 1.467. A point on the braking rate-time curve is determined by taking two different speeds and dividing the difference of the speed in miles per hour by the time interval between them in seconds. It will be noted that the braking rate in this test ranged from 1 1/2 m.p.h.p.s. at the end of the first second, to approximately 4 m.p. h.p.s. just before the car came to a stop.

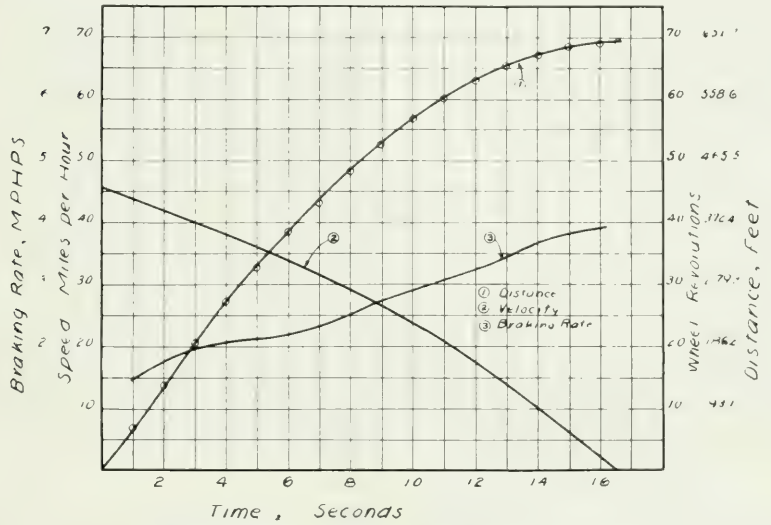


Fig. 38—Analysis of a Distance-Time Curve. Car No. 61.

Braking rates at several different speeds were computed from the chronograph charts and are shown in Table 8-A, Appendix.

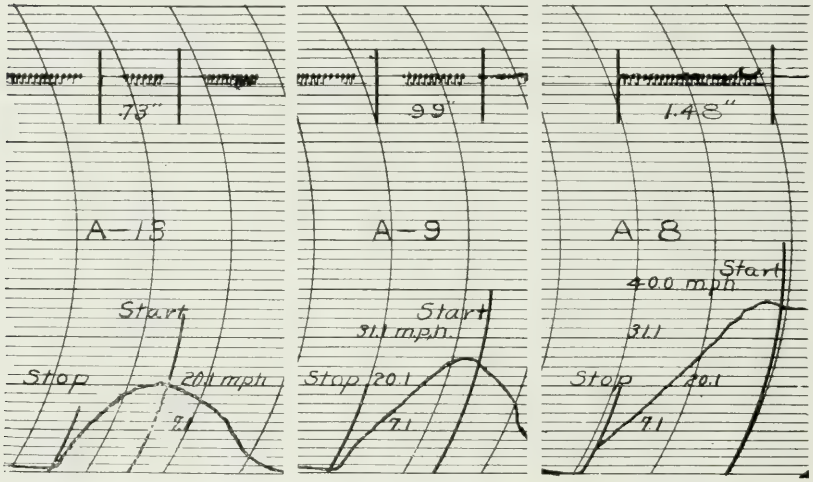
Brake Efficacy. The value of the product of brake rigging efficiency and coefficient of shoe friction have been calculated for the two points in the braking rate curve, Fig. 38, whose values are:

Braking Rate M.P.H.P.S.	Speed M.P.H.
3.80	8.0
2.13	36.2

The train resistance of the car for these speeds were taken from Fig. 25 For the speed of 8 m.p.h. the value of the product is 0.155 and for the speed of 36 m.p.h, 0.082.

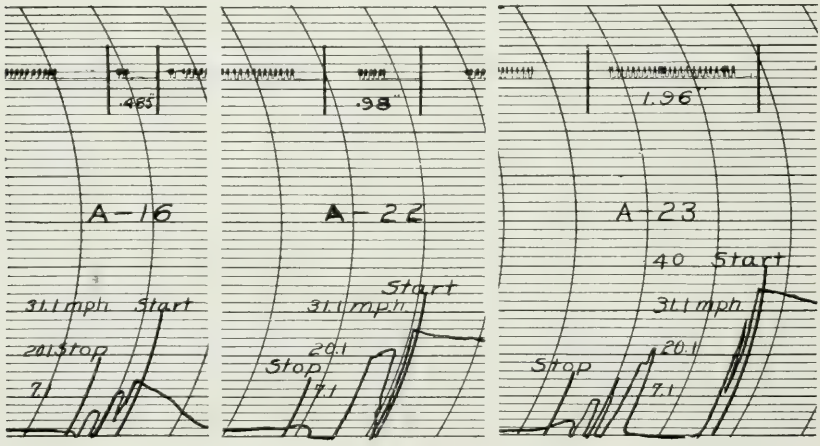
Speed-Time Curves. An analysis of the speed-time curves as recorded by the graphic speedmeter is to be found in Table 6-A.

Appendix. A study of these charts showed that an appreciable interval of time elapsed between the stop indication and the beginning of retardation. An analysis of this time element is set forth in Table 7-A. With air brakes this time delay is chargeable to the time element of the motorman and the time required for the brake cylinder pressure to build up sufficiently to set the brakes. As the braking action with reversed motors starts the instant reversed power is applied the time delay is chargeable to the motorman. That the braking action with bucking motors is quite erratic is shown also by the variations in this time element.



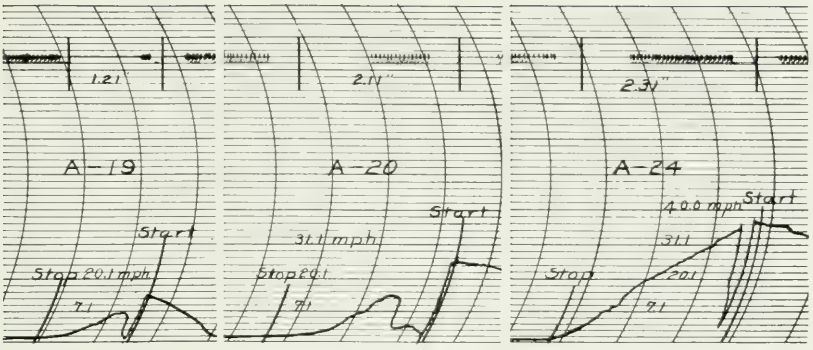
(a) (b) (c)

Fig. 39 Graphic Speedmeter Records, Automatic Air Braking, Car No. 61.



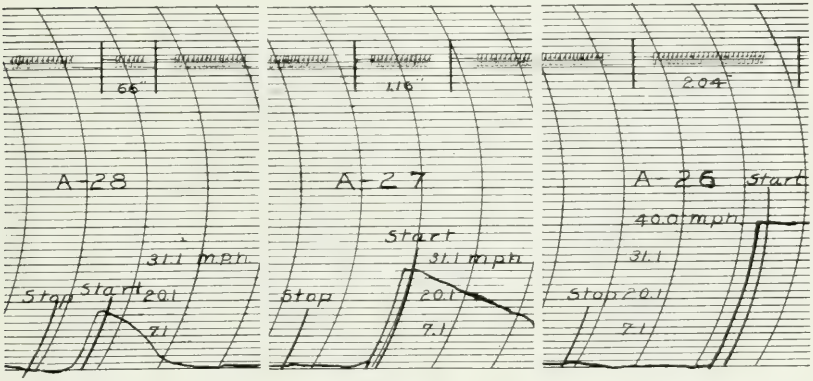
(a) (b) (c)

Fig. 40—Graphic Speedmeter Records, Reversed Motor Braking, Car No. 61.



(a) (b) (c)

Fig. 41—Graphic Speedmeter Records. Bucking Motor Braking. Car No. 61.



(a) (b) (c)

Fig. 42—Graphic Speedmeter Records, Reversed Motor and Automatic Air Braking combined. Car No. 61.

It has not been possible to reproduce all of the graphic speedmeter records but several typical records are shown in Fig. 39 to 42, inclusive.

These charts show very clearly the time interval between the stop indication and the beginning of retardation.

The charts show also that the stops with air brakes were made smoothly with little or no wheel slip. As the speedmeter magneto was connected to a motor-driven axle the erratic appearance of the charts where electric braking was used was due to wheel slippage and in some cases actual reversal of the direction of rotation of the car wheel. Where automatic air and reversed motor braking were combined the charts show that the wheels locked the moment power was applied in the reversed direction.

As might be expected from the appearance of these charts the action of the electric brakes produced very severe strains upon the equipment. Observers along the track reported that the motors flashed very severely under electric braking.

SECTION VI.

Discussion of Test Results, City Car No. 244

This section is devoted to a discussion of the data taken in the tests on the city car, No. 244. The general plan of Section V is followed.

Piston Travel. As may be noted in Table 1-B several measurements of piston travel were made on this car. The measurement was made after the car had come to a stop and is probably greater than a regular standing piston travel test would give. The manufacturer recommends that the standing piston travel for this type of equipment be 4 inches.

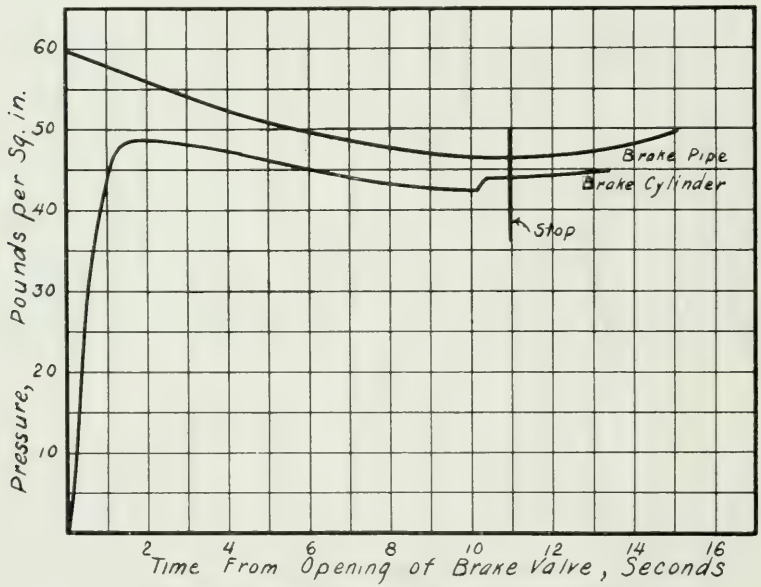


Fig. 43 –A Typical Trainagraph Record, Car No. 244.

Trainagraph Records. The trainagraph record taken in test B-5 is reproduced, somewhat enlarged, in Fig. 43. The pressure marked "brake pipe" is, in the straight air system, the same as the main reservoir pressure. As the main reservoir and brake cylinder are directly connected through the motorman's valve, while the brakes are applied, any reduction in main reservoir pressure is reflected in a similar reduction in brake cylinder pressure. The gradual decrease in pressure as the car came to a stop and the difference between main reservoir and brake cylinder pressure is attributed to leakage and the air sanders which

were operating while the stop was being made. As in the tests on Car No. 61 a slight variation in brake cylinder pressure always preceded the actual stop. Thus in a way the stop was automatically recorded on the trainagraph record. A comparison of the time as measured to this point with that measured to the stop indication made by the time pen of the trainagraph is set forth in Table 11-B, Appendix.

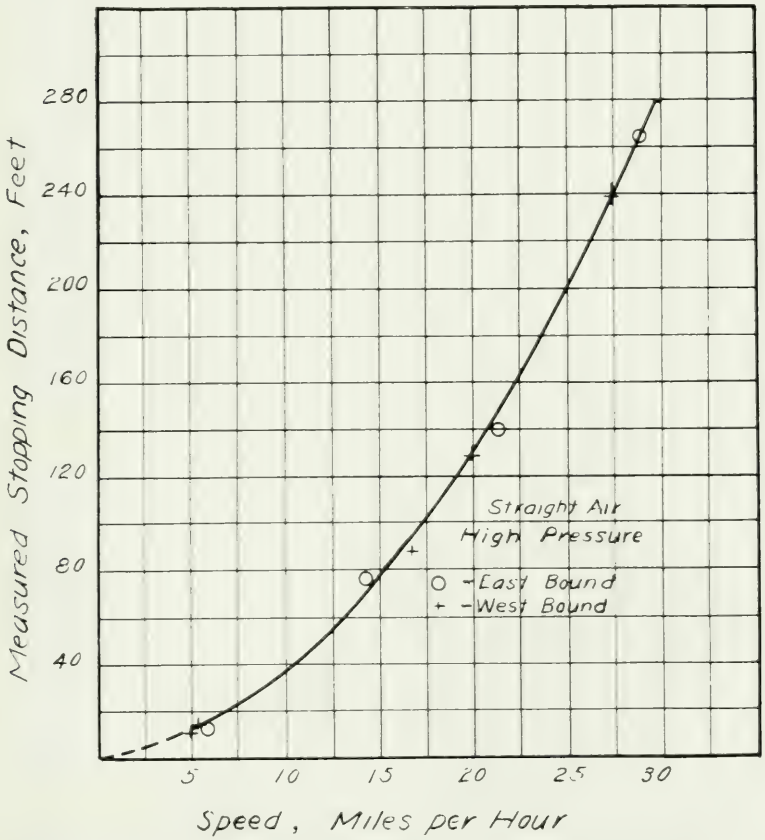


Fig. 44—High Pressure Emergency Air Brake Tests, Car No. 244. Relation Between Distance and Initial Speed.

Fig. 43 shows that a little less than 1 1 2 seconds elapses before the brake cylinder pressure reaches its maximum value. This is less than that required by the automatic air brakes of Car No. 61. An analysis of this and other time elements is presented in Table 5-B Appendix. while an analysis of other factors shown by the trainagraph record is shown in Table 4-B, Appendix.

The sander was stopped when the car came to a standstill and the compressor being running, the pressure curves rise again.

Stopping Distance. Fig. 44 shows the relation between initial speed and stopping distance for the test runs made with the main reservoir pressure at the upper limit of the governor range, 70 lb. per sq. in. The runs both east and west bound gave very consistent data. A similar curve for tests at the lower limit of the governor range, 60 lb. per sq. in., run east bound is

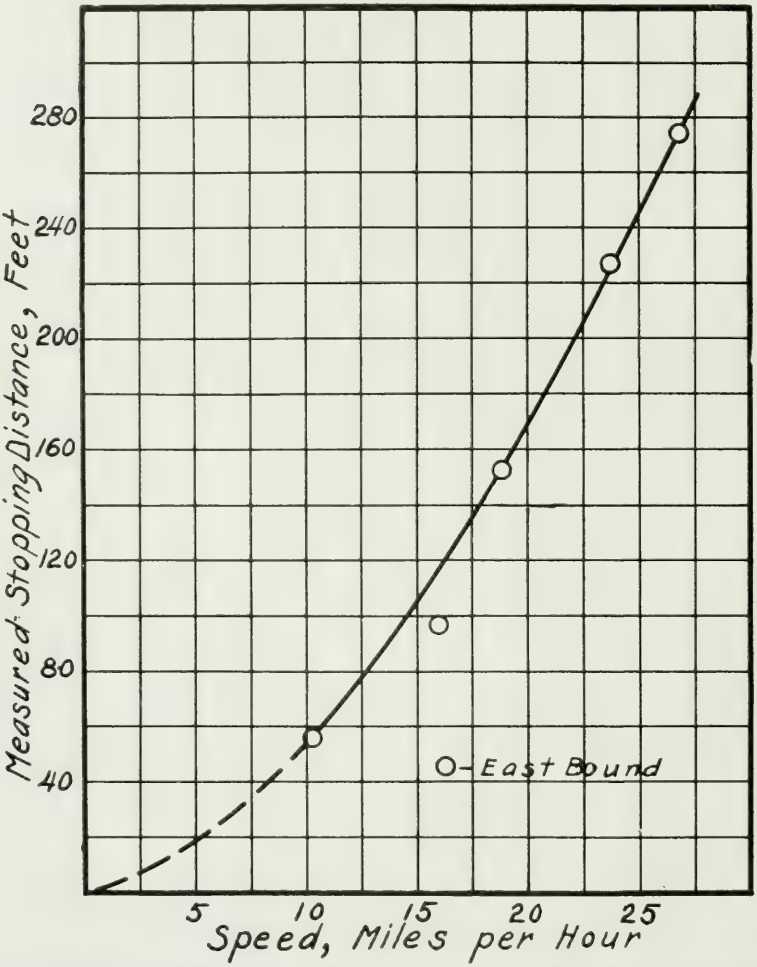


Fig. 45—Low Pressure Emergency Air Brake Tests, Car No. 244. Relation Between Distance and Initial Speed.

shown in Fig. 45. The two curves are compared in Fig. 46. The comparison illustrates in a striking manner the effect of 10 lb. per sq. in. difference in main reservoir pressures on the braking action of the car.

The high pressure air curve is redrawn as a reference line in Fig. 2 and the points for the various electrical tests are plotted

on the same sheet. For this car and the track conditions at the time of the test, braking by reversed motors gave decidedly superior results as far as distance traveled is concerned. It will be noted, Table 1-B, Appendix, however, that the circuit breaker "blew" in several of the reversed motor tests and that in one instance the circuit breaker was thrown to put out an arc in the controller. In those tests where the breaker blew, the car was brought to a stop without further action on the part of the motorman by the motors going automatically into bucking motor braking.

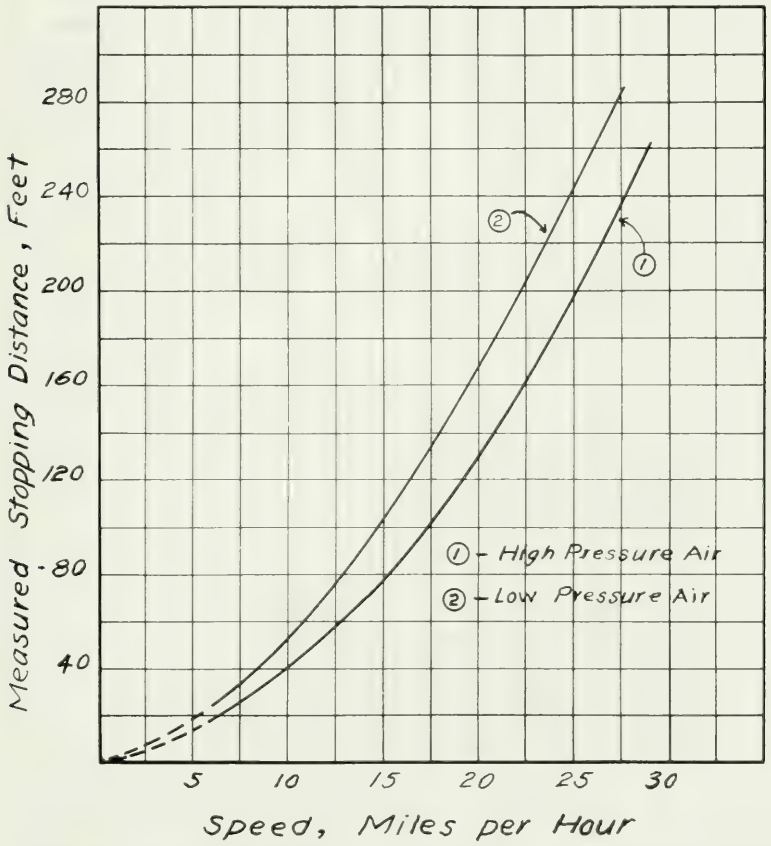


Fig. 46—Comparison of High and Low Pressure Emergency Air Brake Tests, Car No. 244.

In Fig. 44 the highest point marked on the curve has the coordinates of 28.8 m.p.h. and 264.5 ft. These are the data from Run No. B-9 and from Table 3 it is seen that the mean braking rate is 2.77 m.p.h.p.s. and the time is 10.4 seconds. Had this braking rate been uniform throughout the braking period the theoretical distance would have been 220 ft.

Similarly, for the lowest point on the curve, east bound Run No. B-10, the initial speed is 5.7 m.p.h., the stopping time, 2.8 sec., the distance, 14 ft. and the mean braking rate 2.0 m.p.h.p.s. The theoretical stopping distance, based on a uniform braking rate, is 11.7 ft.

Stopping Time. An analysis of the relation between stopping time and initial speed is presented in Fig. 47, 48 and 49. Fig. 47 is for high pressure air with the car operated in both

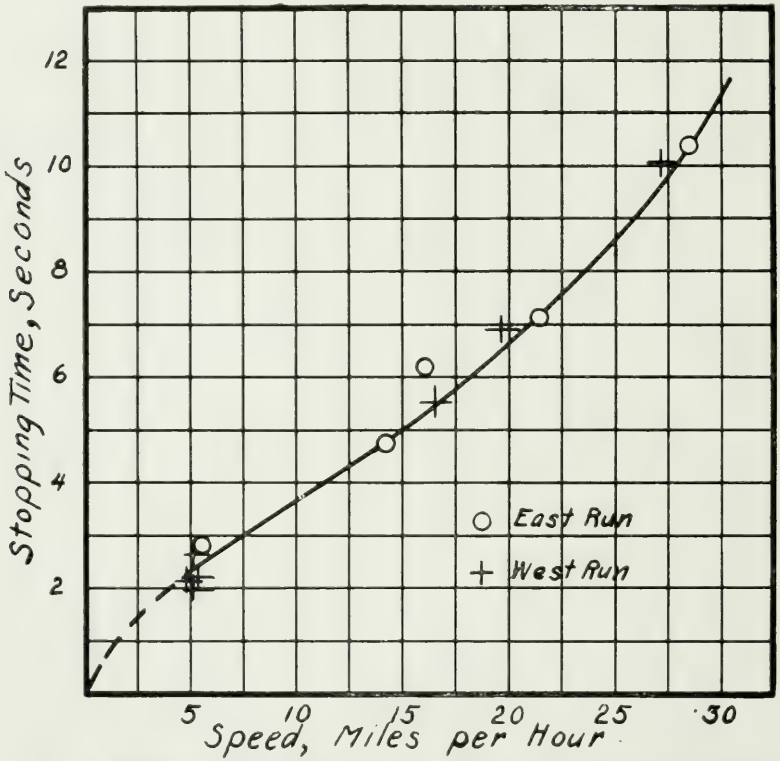


Fig. 47—High Pressure Emergency Air Brake Tests. Car No. 244. Relation Between Time and Initial Speed.

directions and Fig. 48 is for low pressure air, the car running east bound. These two curves were redrawn in Fig. 49 and the points for the various electric braking tests were plotted on the same sheet to facilitate comparison. Table 10-B, Appendix, is a comparison of the time data as determined by several methods, the time determined by the chronograph being considered the most accurate.

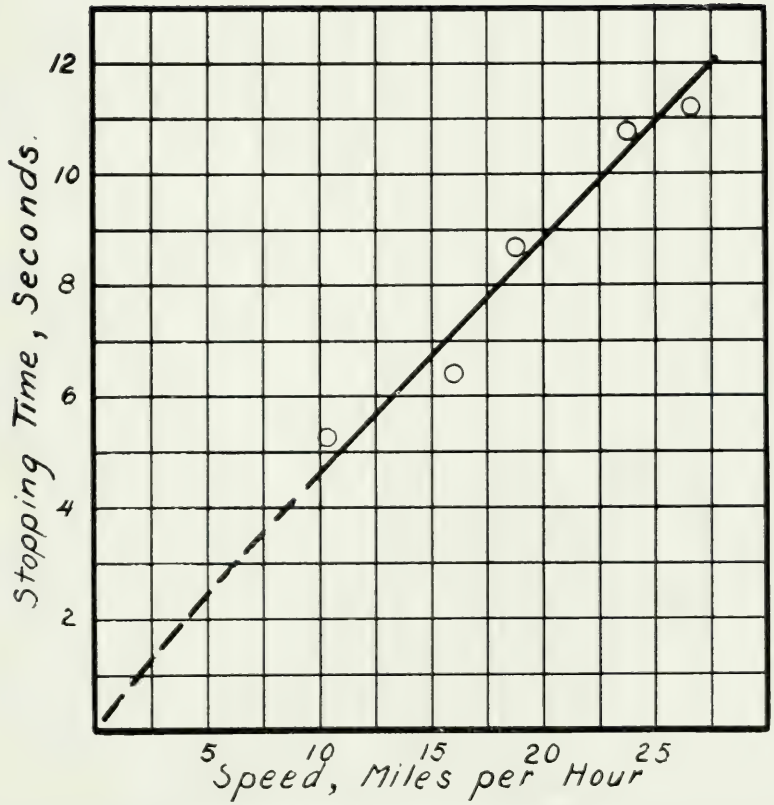


Fig. 48—Low Pressure Emergency Air Brake Tests. Car No. 244. Relation Between Time and Initial Speed.

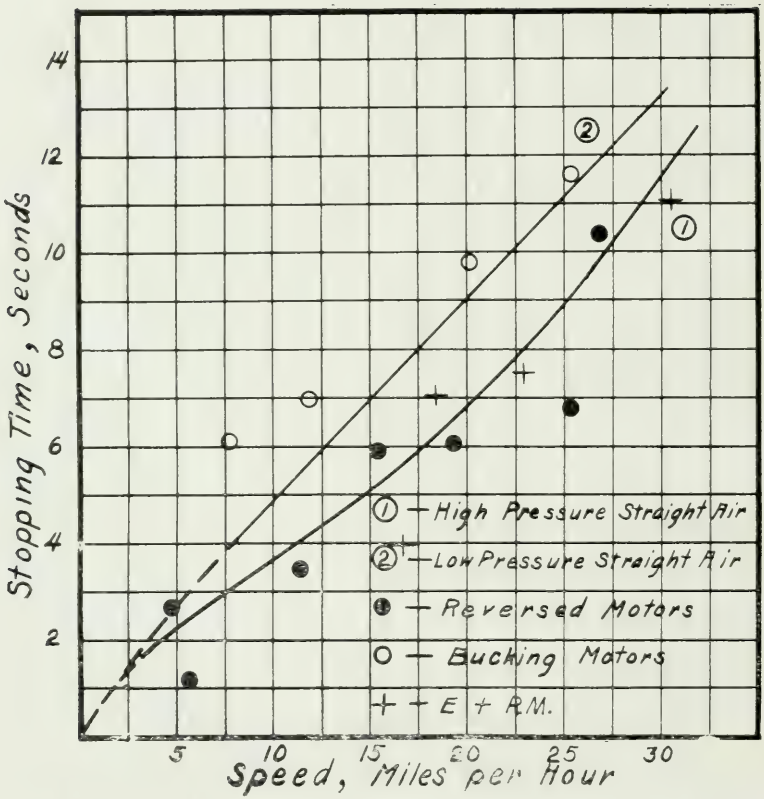


Fig. 49.—Relation Between Time and Speed, for the Various Methods of Braking. Car No. 244.

Comparison of Distance Measurements. The discrepancy between distance as measured by the tape and by the chronograph is shown in Fig. 50. Had the two methods tallied the full line would have coincided with the dashed line. The reasons for the discrepancy are the same as those set forth in the similar discussions of the test data taken on Car No. 61. Table 9-B, Appendix, contains the data from which the points in Fig. 50 were plotted.

On this car one wheel revolution corresponds to 7.78 ft.

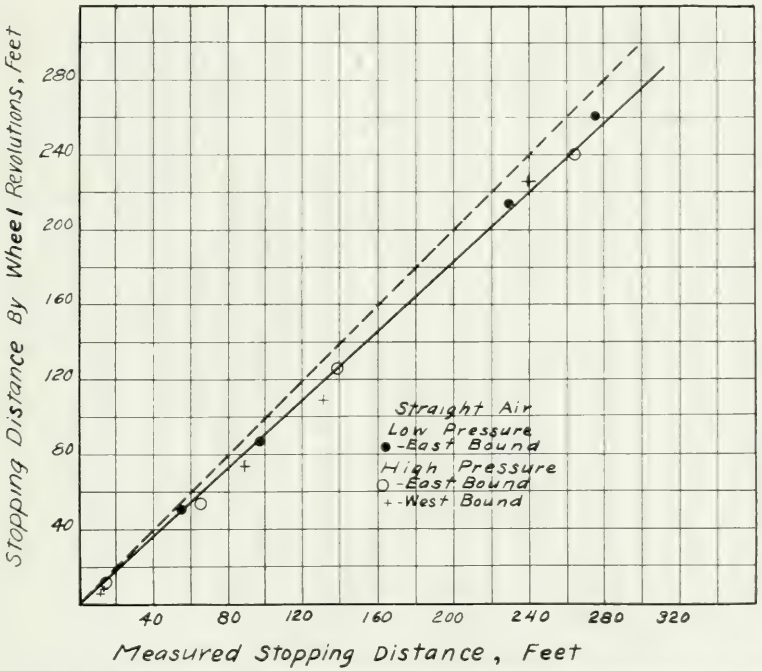


Fig. 50—A Comparison of the Stopping Distances as Determined by Two Methods. Car No. 244.

Distance—Time Curves. Distance-time curves for test runs, B-2, B-3 and B-5 are shown in Fig. 51. They were plotted from the data contained in Table 3-B, Appendix, in which is tabulated the wheel revolution-time analysis of such of the chronograph records as were complete.

Analysis of the Distance-Time Curve. The distance-time curve for test No. B-4 has been plotted in Fig. 52. From it were derived the speed and braking rate curves shown in the same figure. Braking rates at different speeds, calculated directly from the chronograph record, are shown for a number of runs in Table 8-B, Appendix.

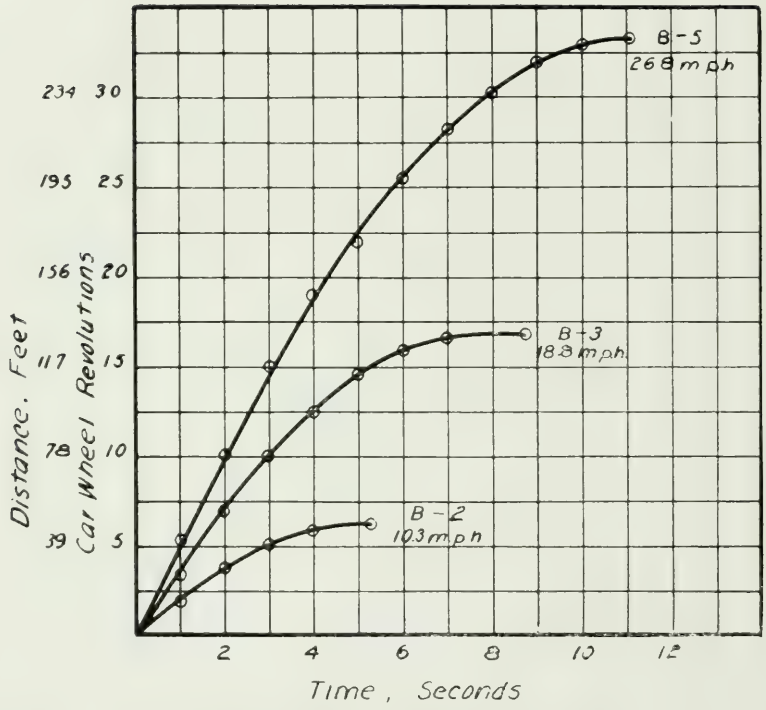


Fig. 51—Typical Distance-Time Curve, Car No. 244.

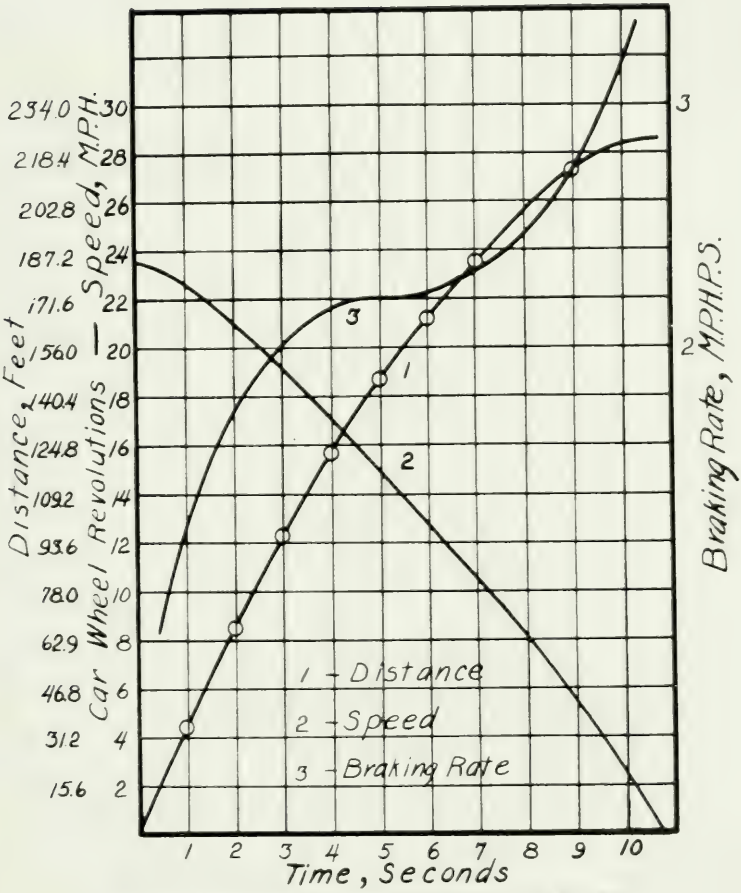
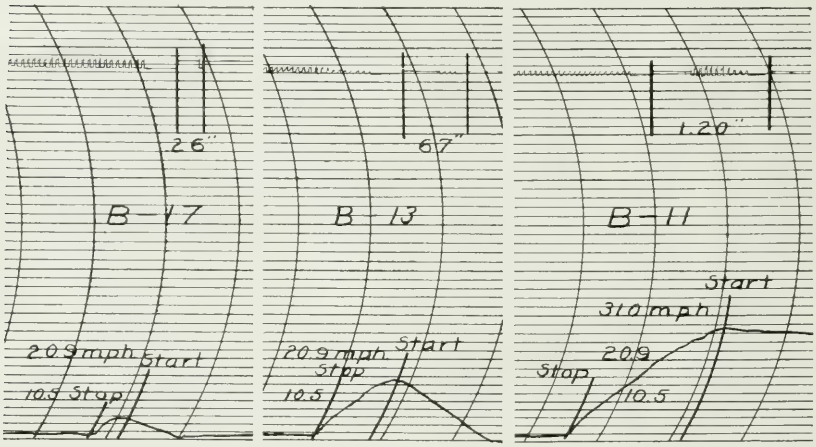


Fig. 52—Analysis of a Distance-Time Curve, Car No. 244.

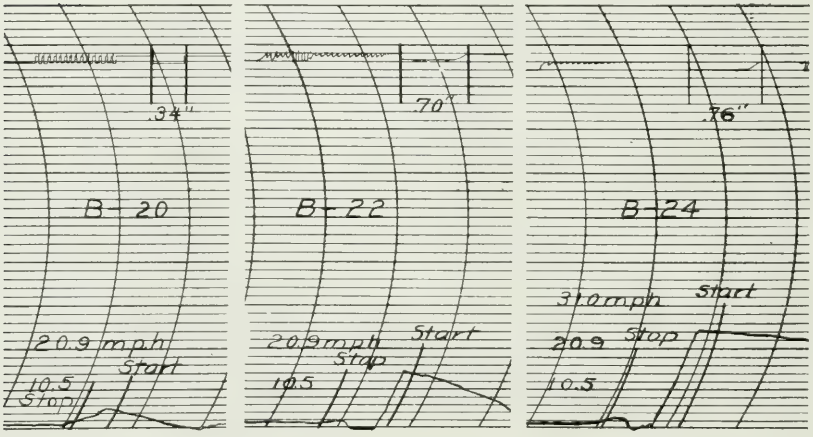
Braking Efficacy. The product of brake rigging efficiency and coefficient of shoe friction has been evaluated for the points on the braking rate curve, Fig. 52, whose values are 2.2 and 3.0 m.p.h.p.s. These points correspond to speeds of 16 and 3.6 m.p.h. respectively. For the first point, the value of the product is 0.138 and for the second 0.195.

Speed-Time Curves. Table 6-B, Appendix, contains an analysis of the speed-time curves recorded by the graphic speedmeter. As in the tests on Car No. 61 a definite time interval elapsed between the operation of the brake valve contact and the beginning of retardation. This time element for Car No. 244 is analyzed in Table 7-B, Appendix.



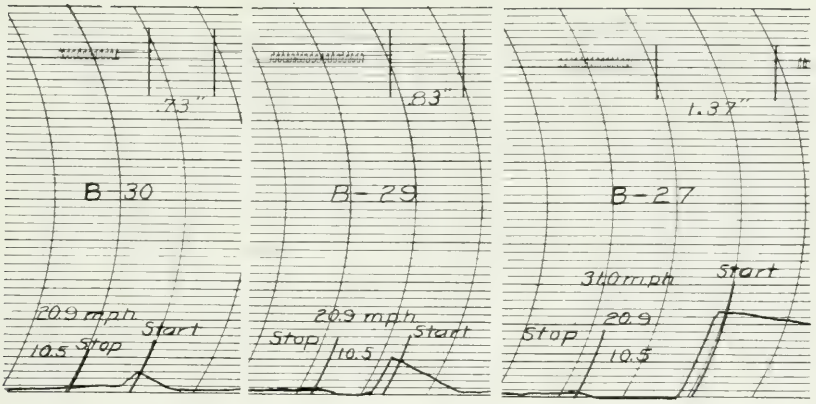
(a) (b) (c)

Fig. 53—Graphic Speedmeter Records, Emergency Air Braking, Car No. 244.



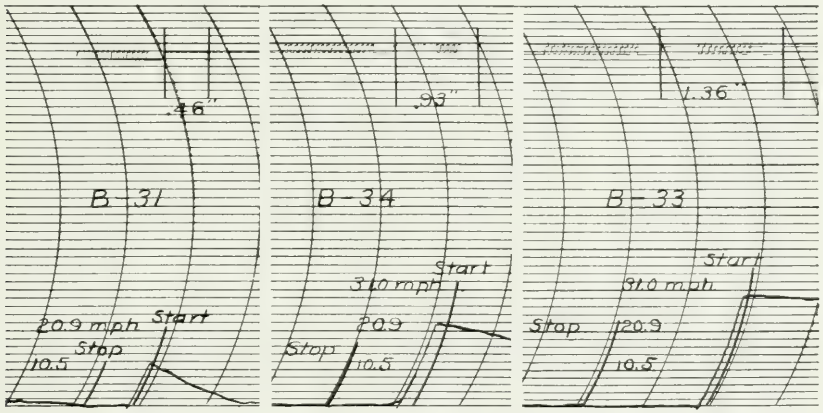
(a) (b) (c)

Fig. 54—Graphic Speedmeter Records, Reversed Motor Braking, Car No. 244.



(a) (b) (c)

Fig. 55—Graphic Speedmeter Records, Bucking Motor Braking, Car No. 244.



(a) (b) (c)

Fig. 56—Graphic Speedmeter Records, Reversed Motor and Emergency Air Braking, Car No. 244.

Four sets of speed-time curves are reproduced in Fig. 53, to 56, inclusive. Two of the reversed motor tests, Fig. 54 (*b*) and (*c*), show reversed rotation of the wheel to which the speed recording mechanism was attached. The same is true of Fig. 55 (*b*) and (*c*) while with reversed motors and emergency air the wheels slipped from the instant reverse power was applied.

SECTION VII

Discussion of Test Results, City Car No. 1026

This car is a fairly heavy city car, arranged for single end operation. It is equipped with two motors which are carried on the front and the rear axles, of the rear truck. The axle contact and speedmeter were connected to the rear axle of the front truck, a non-driven axle. A copy of the test log is shown in Table

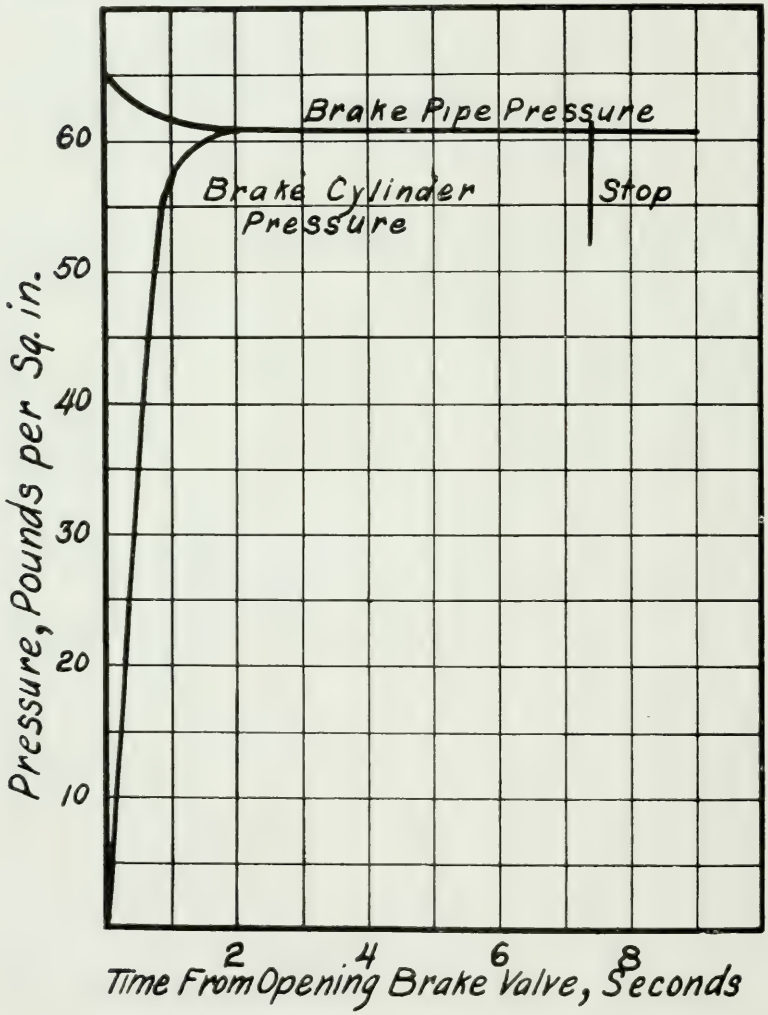


Fig. 57.—A Typical Trainagraph Record. Car No. 1026.

1-C, Appendix. It will be noted that this car is equipped with a hand sander and that a defective circuit breaker made it necessary to pull the trolley pole in many of the electrical tests.

Piston Travel. It will also be noted from Table 1-C that the piston travel was 4 3/16 inches. The measurement was made after the car had come to a standstill in one of the braking tests. As with Car No. 244 the travel is probably greater than would have been measured in a static shop test. The air brake equipment on this car is of the same type as that on Car No. 244.

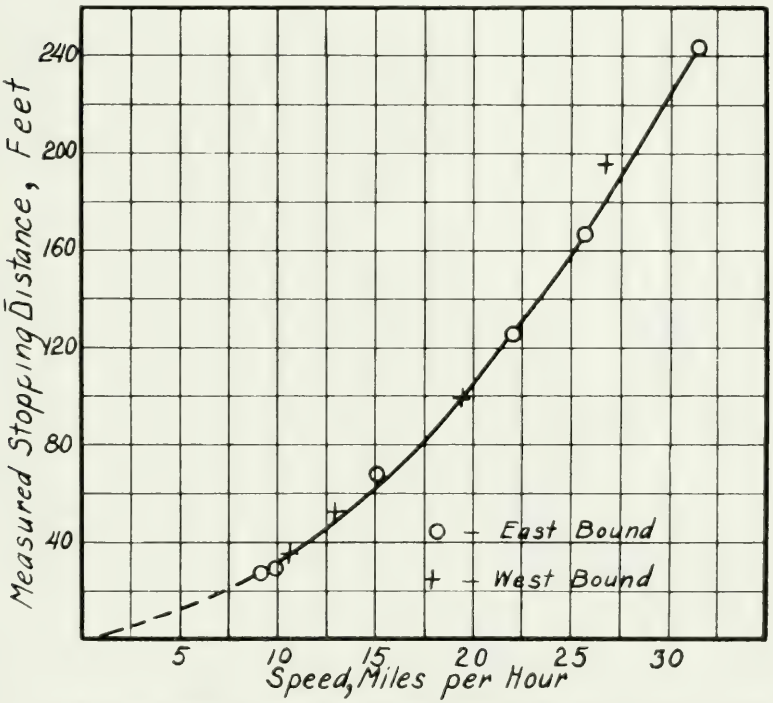


Fig. 58—High Pressure Emergency Air Brake Tests. Car No. 1026. Relation Between Distance and Initial Speed.

Trainagraph Records. Table 4-C, Appendix, contains an analysis of the trainagraph records taken in the tests on this car. The trainagraph record, enlarged, for test No. C-7, is reproduced in Fig. 57. The variations in brake cylinder pressure which appeared on the trainagraph records for Cars No. 61 and 244 just prior to the stop do not appear on the records for this car. An analysis of the time interval required for the pressure in the brake cylinder to build up to its full value is contained in Table 5-C, Appendix. For this car this time interval had a mean value of about one second.

Stopping Distance. As with Car No. 244 air brake tests both at the upper limit, 65 lb. per sq. in., and the lower limit, 55 lb. per sq. in., of the compressor governor range were run on this car. Fig. 58 shows the measured stopping distances for different initial car speeds with the air pressure at the upper limit. The curve was drawn for the east bound points but it also fits the west bound points very well. The low pressure curve is reproduced in Fig. 59, while Fig. 60 shows a comparison between the two curves. An increase of 10 lb. per sq. in. air pressure does not increase the effectiveness of the brakes as much as it did on Car

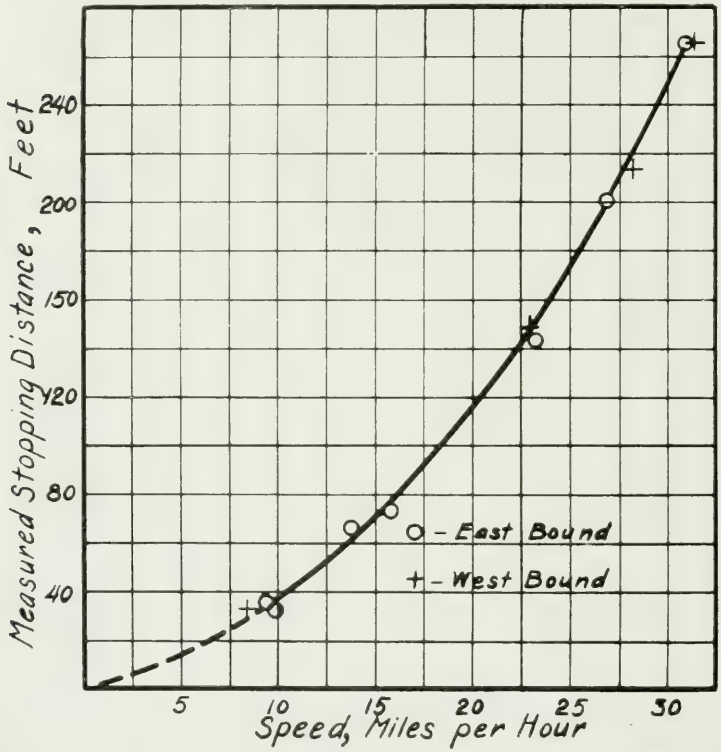


Fig. 59 -Low Pressure, Emergency Air Brake Tests, Car No. 1026. Relations Between Distance and Initial Speed.

No. 244. In Fig. 3 the high pressure air curve has been redrawn and plotted on the same sheet are the points for the electrical braking tests. The points for the tests where both reversed motor and air braking were used fall on this curve in the east bound runs while two of the west bound runs gave results better than when emergency air was used alone. The purely electrical tests gave inferior results.

In the reversed motor braking tests the circuit breaker "blew" frequently and the trolley pole had to be pulled down to extinguish the arc. The bucking motor tests were very inferior as far as results were concerned. The upper point marked on the curve in Fig. 58 is for test No. C-2. The speed for this point is 31.5 m.p.h., the time 8.5 sec., the distance 243.1 ft. and the braking rate 3.7 m.p.h.p.s. (See Table 4.) Had the braking rate been uniform during the interval of time which elapsed while the stop was being made the distance would have been 196.5 ft. Similarly for the low point on the curve, test No C-6, the initial speed was 9.1 m.p.h., the time 3.1 sec., the distance 27.7 ft., and the mean braking rate 2.94 m.p.h.p.s. The theoretical distance in this case is 20.7 ft.

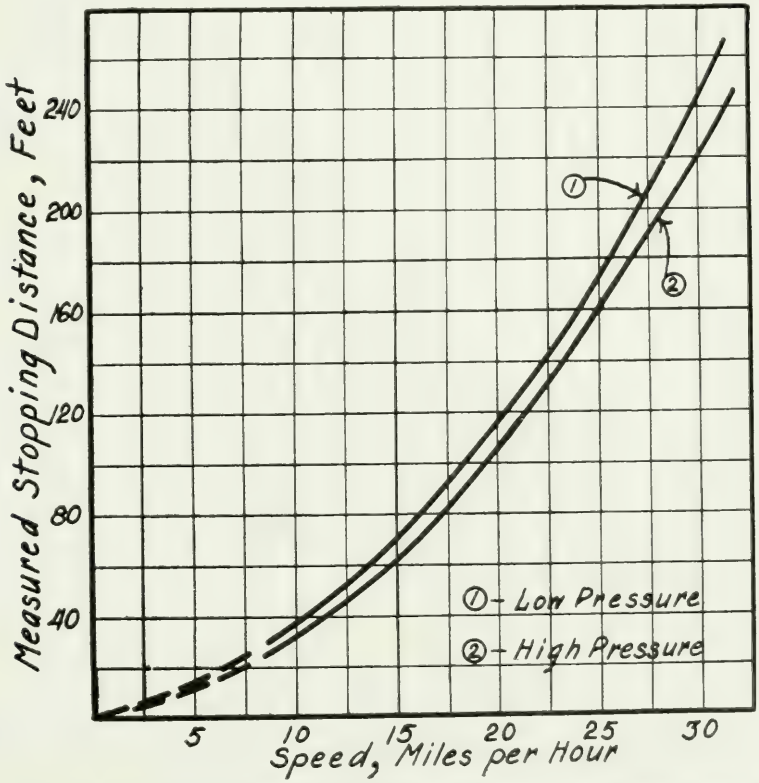


Fig. 60—Comparison of High and Low Pressure Emergency Air Brake Tests. Car No. 1026.

Stopping Time. The time required to bring the car to a stop in each test is shown in Table 2-C, Appendix. While a comparison of this time interval as determined by several methods is presented in Table 10-C, Appendix. The relation between

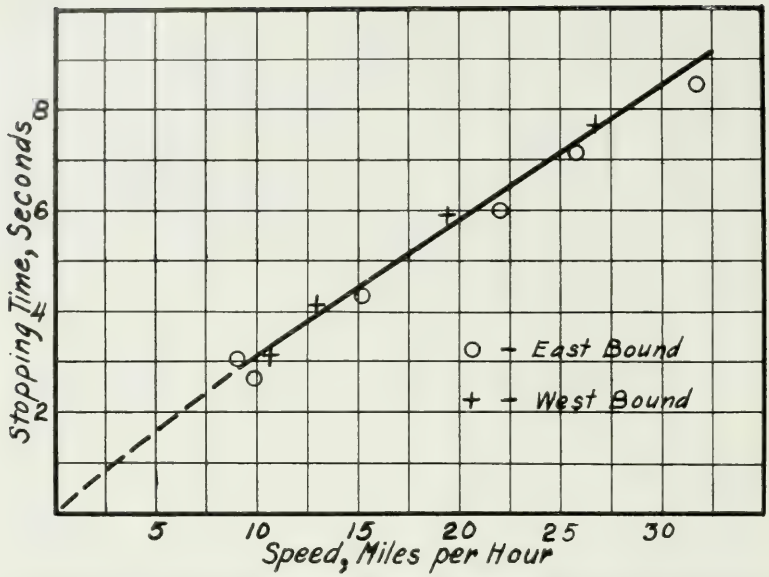


Fig. 61 —High Pressure Emergency Air Brake Tests, Car No. 1026. Relation Between Time and Initial Speed.

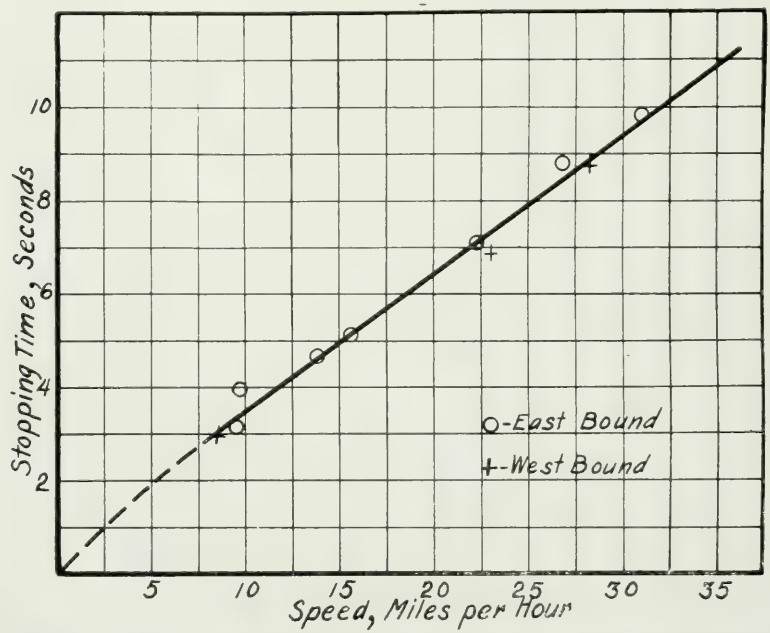


Fig. 62—Low Pressure Emergency Air Brake Tests, Car No. 1026. Relation Between Time and Initial Speed.

stopping time, as determined by the chronograph, and initial speed is presented graphically in Fig. 61, 62 and 63. Conclusions drawn from the time-speed graphs would be similar to those drawn from the distance-speed graphs.

Comparison of Distance Measurements. A comparison of the stopping distance as determined by several methods is presented in Table 9-C, Appendix. This comparison is similar to that made for the other cars. Fig 64 compares the distance as

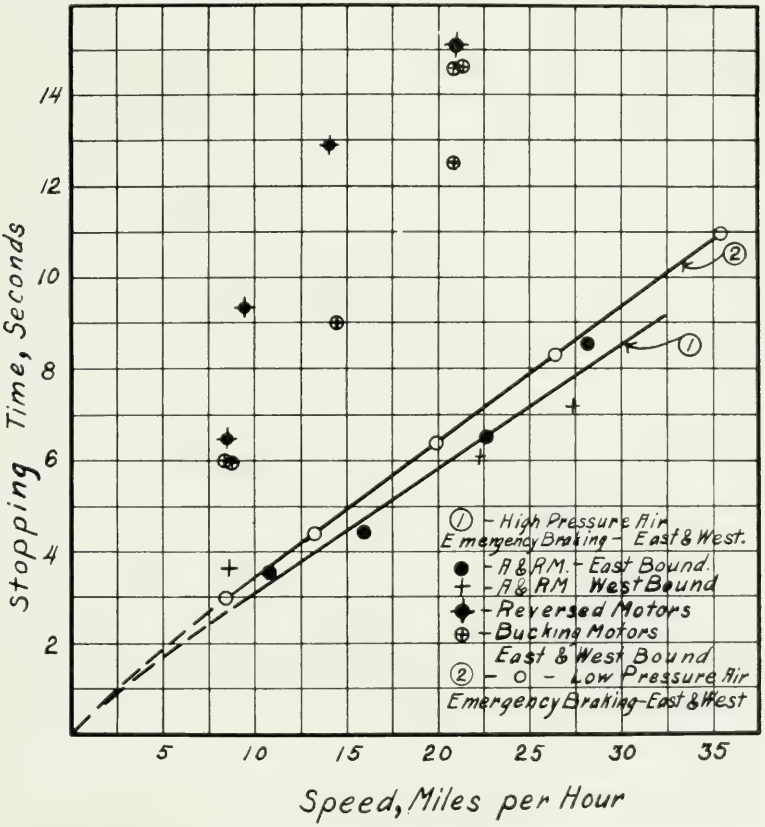


Fig. 63—Relation Between Stopping Time and Speed for the Various Methods of Braking. Car No. 1026.

determined from the chronograph records with the measured distance for some of the tests. Had the two methods given results in agreement the full lines would have coincided with the dashed line. As the wheel to which the contact making device was attached on this car was non-motored the action with the reversed motor and emergency air braking combined was very similar to that with the air brake alone. The motored wheels

skidded as they did on the other cars, but the non-motored wheels continued to revolve although the curve indicates that there was probably more sliding than with the air brakes acting alone.

The circumference of the wheel to which the contact maker was attached was 8.15 ft.

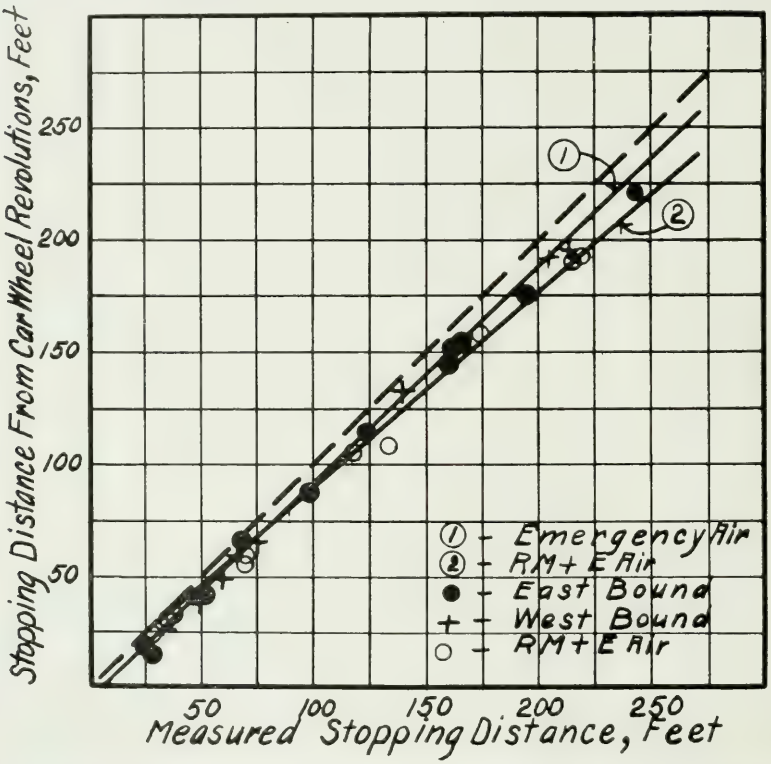


Fig. 64—A Comparison of the Stopping Distances as Determined by Two Methods, Car No. 1026.

Distance-Time Curves. The number of wheel revolutions which occurred up to the end of the first, second, third, etc., seconds for each test run on this car are set forth in Table 3-C, Appendix. Several typical distance-time curves are plotted in Fig. 65.

Analysis of a Distance-Time Curve. The distance time curve for test run No. C-2 has been plotted and analyzed in Fig. 66. The braking rate varied through a wide range of values. Braking rates at several different speeds are shown in Table 8-C for a number of runs. The runs were selected more or less at

random from those whose chronograph records were complete and showed little or no wheel slippage.

Brake Efficacy. For the two points on the braking rate curve, Fig. 66, corresponding to speeds of 14.75 m.p.h. and 25.5. m.p.h. and braking rates of 2.75 m.p.h.p.s. and 4.25 m.p.h.p.s,

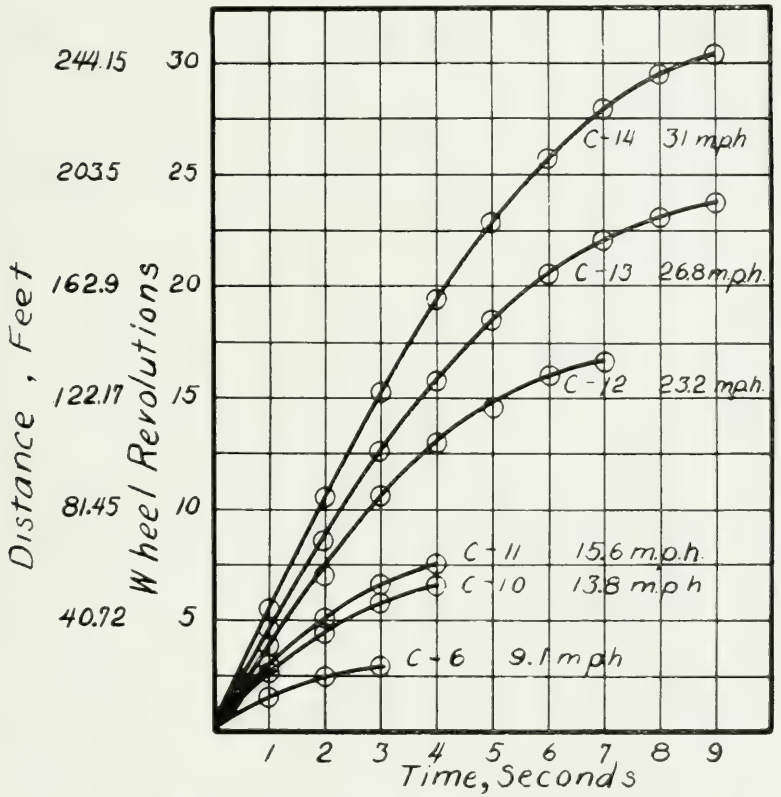


Fig. 65—Typical Distance, Time Curves, Car No. 1026.

respectively, the value of the product of brake rigging efficiency and shoe friction have been computed. For this car the values are high being 0.295 at 25.5 m.p.h. and 0.194 at 14.75 m.p.h. Minor undulations in the track were, of course, neglected in the calcuation of these values although such minor undulations might effect the magnitudes somewhat. Only by making similar computations for a large number of runs in both directions and taking the mean could the effect of track profile variations and wind resistance be minimized.

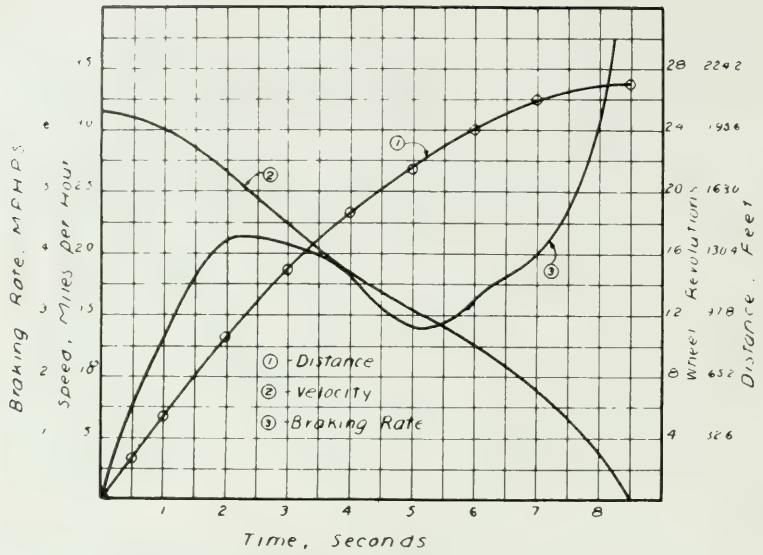
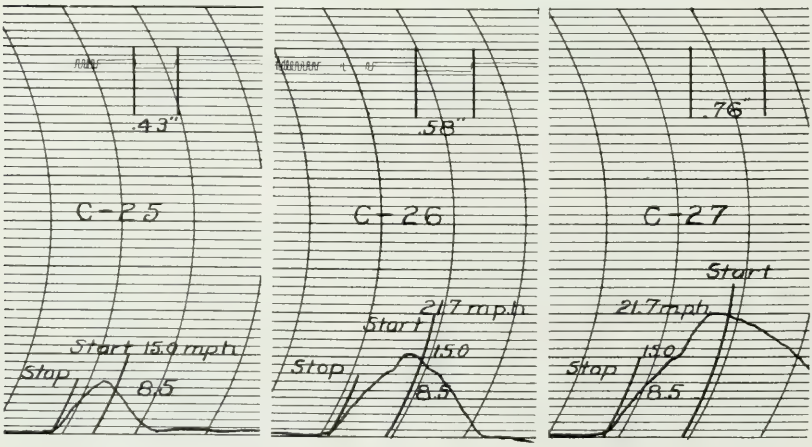


Fig. 66—Analysis of a Distance Time Curve. Car No. 1026.

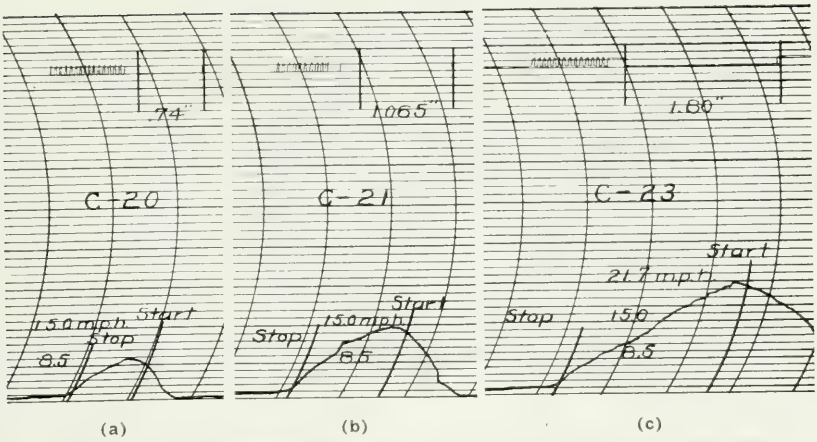
Speed-Time Curves. The graphic speedmeter records taken in the tests on this car are of particular interest since the magneto was driven by a non-motored wheel.

Fig. 67, 68 and 69 show typical records. Those in Fig. 67 are for air brake tests and are similar to those taken on the other cars. They do show, however, as does the braking rate curve in Fig. 66, a marked variation in braking rate during the stop.



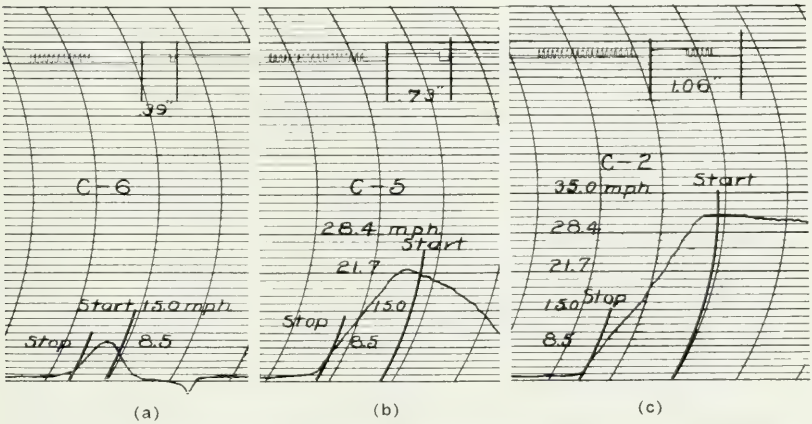
(a) (b) (c)

Fig. 67—Graphic Speedmeter Records. Emergency Air Braking, Car No. 1026.



(a) (b) (c)

Fig. 68—Graphic Speedmeter Records, Bucking Motor Braking, Car No. 1026.



(a) (b) (c)

Fig. 69—Graphic Speedmeter Records, Reversed Motors and Emergency Air Braking, Car No. 1026.

The cause of this is not apparent. It was not possible to get good results with reversed motor braking on this car but bucking motor curves are shown in Fig. 68. As a rule the braking rate is very erratic in bucking motor tests but the graph for test No. C-23 is a very good one.

A comparison of these records with those obtained on the other cars where the speedmeter was driven from a motored wheel is of value in showing the erratic action of the motored wheels in electric braking.

An analysis of speedmeter records is contained in Table 6-C, Appendix.

In Table 7-C, Appendix, is listed the results of a study of the time interval elapsing between the stop indication given by the time pen and the point on the speed time graph at which retardation commenced.

SECTION VIII

Discussion of Test Results, Birney Car No. 55

Because of the large number of the so-called Birney Safety Cars which have been placed in operation during the last few years, and the paucity of published data relative to their braking ability the tests on Car No. 55 are of especial interest. As will be seen from an inspection of the log sheets, Table 1-D, Appendix, a large number of test runs were made on this car. Chronograph trouble was partly responsible for the large number of tests but also it was desired to give this car a very thorough trial. As the car is very light in weight, (See Table 1) it was decided

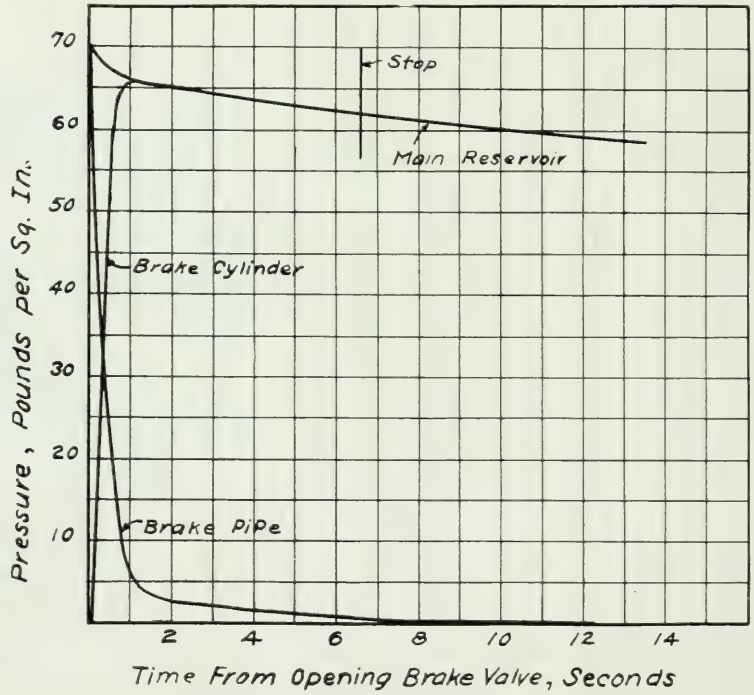


Fig. 70—A Typical Trainagraph Record. Car No. 55.

to run tests with the car carrying approximately full load and with it carrying only those persons needed to operate the testing equipment.

This car is equipped for double end operation but is ordinarily operated on a loop run. It had been planned to run tests, operating in one direction from the No. 1 end and in the other direc-

tion from the No. 2 end. As the No. 2 end is rarely used in regular service both the sanders and the circuit breaking cylinder gave trouble and all of the tests were made with the car operated from the No. 1 end.

Piston Travel. The brake cylinder piston travel was measured at the end of several of the test runs (See Table 1-D, Appendix). Although the brake cylinder on this car is 6 inches in diameter by 12 inches in length the manufacturer in his instruction book recommends that the standing travel should be adjusted to not more than 4 inches. The measured travel ranged from 7 1/4 to 7 3/4 inches. As this was measured just after an emergency stop the travel was probably somewhat greater than it would have been for a shop test.

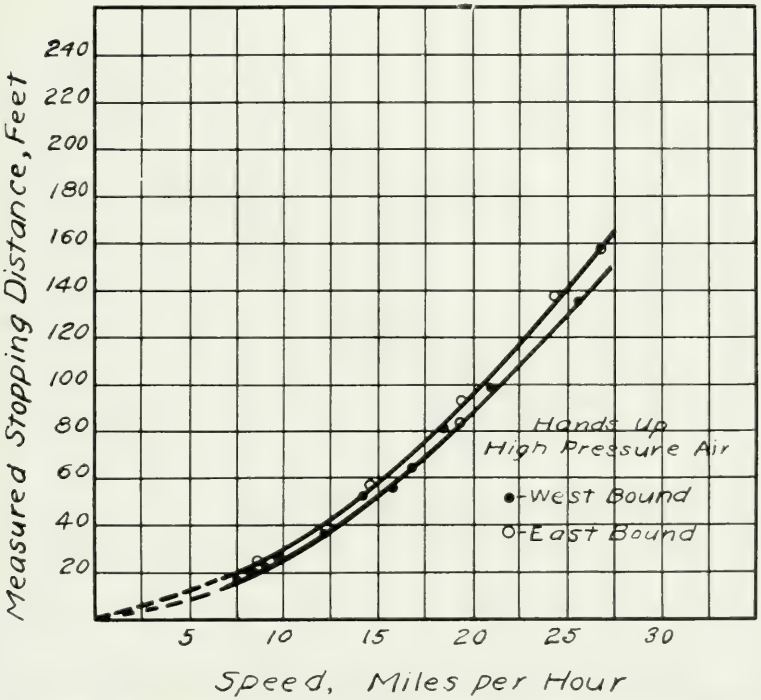


Fig. 71—High Pressure, Hands Up. Air Brake Tests. Car No. 55 Loaded. Relation Between Distance and Initial Speed.

Trainagraph Records. The trainagraph records taken in the tests on this car are analyzed in Tables 4-D and 5-D, Appendix. Fig. 70 shows a typical trainagraph record test No. D-37, enlarged, and arranged for convenient reading. The brake cylinder and main reservoir pressure follow the same line after the pressures have equalized. In the tests where the operation of the "deadman's" device on the controller, designated in these

tests. "Hands Up", inaugurated the braking, the brake cylinder pressure reached its full value in about 0.9 second. In the tests designated "Emergency", the brake valve was thrown to the emergency position. For these tests approximately 1.2 seconds were required for the brake cylinder pressure to reach its maximum value. (See Table 5-D, Appendix.)

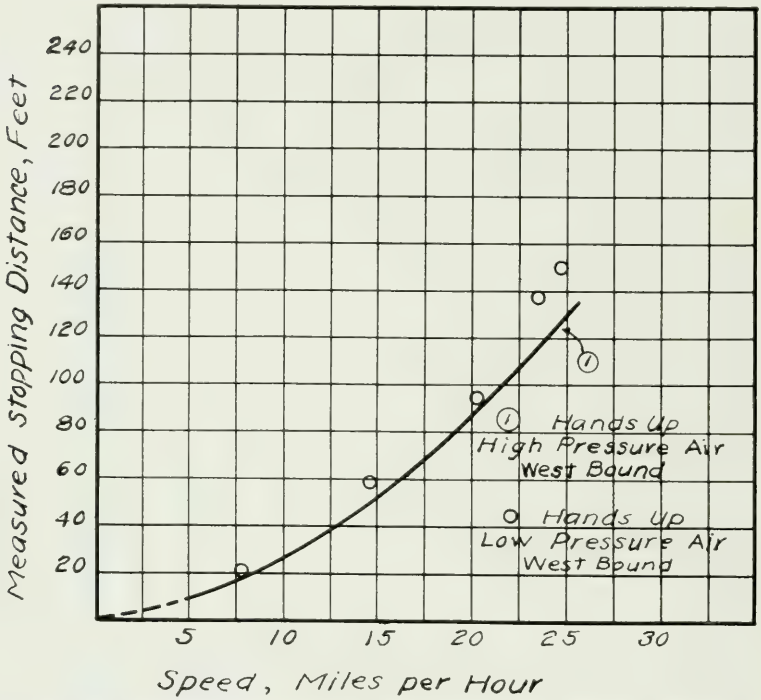


Fig. 72 -Comparison Between High Pressure and Low Pressure, Hands Up, Air Brake Tests, Car No. 55, Loaded.

Stopping Distances. Tests were run with main reservoir pressures both at the upper limit, 70 lb. per sq. in., and at the lower limit, 60 lb. per sq. in. of the pressure range of the compressor governor. Fig. 71 compares the results for east and west bound runs at high pressure, "Hands Up" braking. The westerly wind prevailing seemed to affect this car much more than it did the others and the two sets of points fall on lines which are distinctly different. The curve for the west bound runs has been redrawn in Fig. 72 and points for low pressure runs plotted on the same curve sheet. While the high pressures gave better braking the difference between high and low pressure braking is less than for Cars No. 244 and 1026.

Fig. 73 and Fig. 74 show similar curves for those tests in which the brakes were applied by moving the brake valves to the

emergency position, the power being cut off by throwing the controller to the "off" position.

Fig. 75 shows that stopping the car by permitting the safety feature on the controller handle to operate is appreciably more effective than throwing the brake valve to the emergency position and the controller to the "off" point.

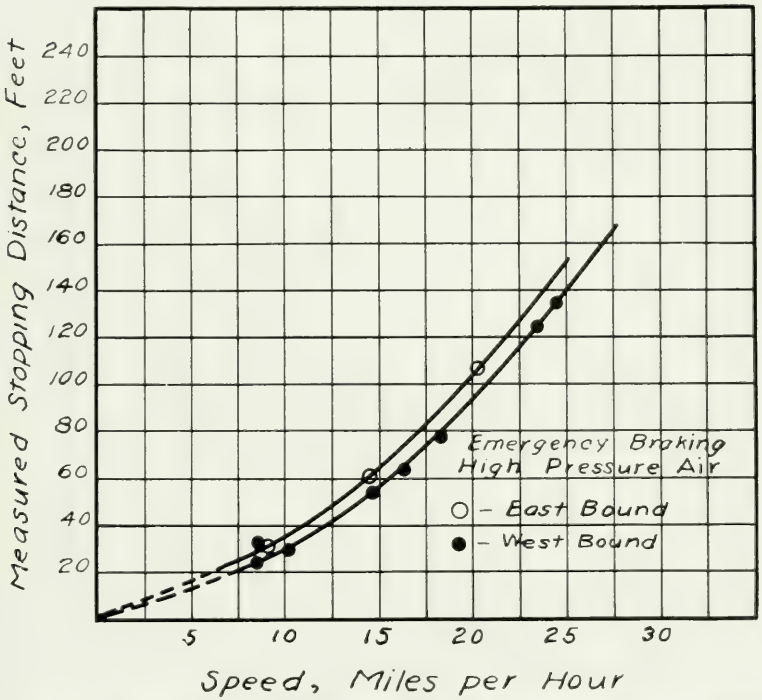


Fig. 73—High Pressure Emergency Air Brake Tests. Car No. 55 Loaded. Relation Between Distance and Initial Speed.

A comparison of the high pressure, "Hands Up" curve with the points secured in the electrical tests Fig. 4 shows that the air brakes constitutes the most effective way of stopping this car. Owing to the position of the circuit breaker on these cars, braking by bucking motors consumes considerable time on the part of the motorman before braking action can begin. While the braking power on this car is very high (see Table 15) the stops made by the air brakes were very smooth except for the lurch at the instant of stopping. Although the braking rates with the air brakes were much higher than with electric braking the shock to equipment was very much less. Because of the severity of the strains caused by electric braking, tests were not made with initial speeds above 20 m.p.h.

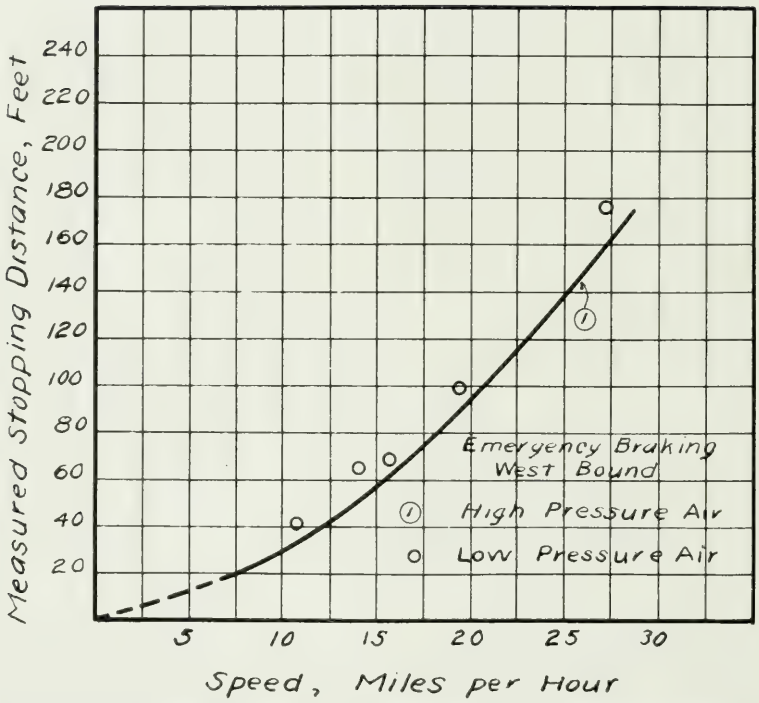


Fig. 74—Comparison Between High Pressure and Low Pressure Emergency Air Brake Tests, Car No. 55 Loaded.

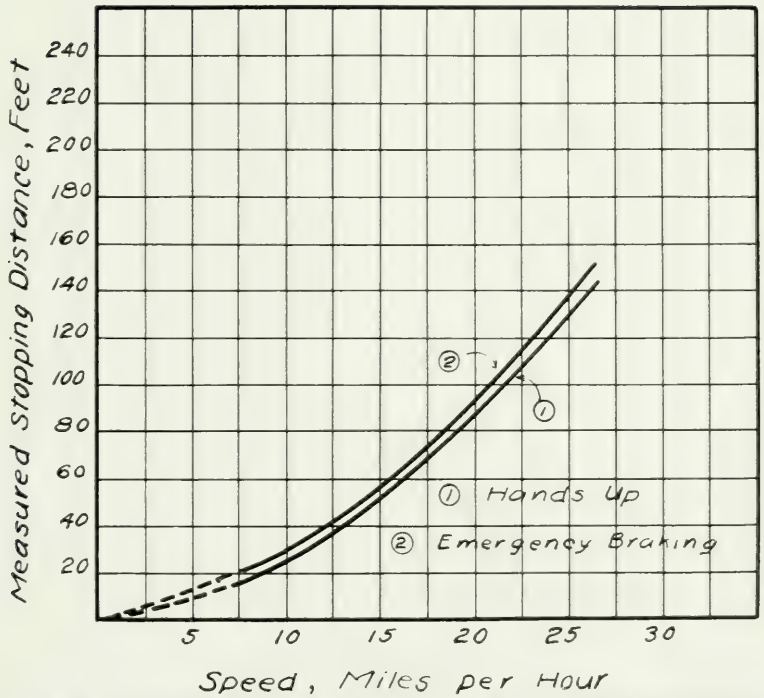


Fig. 75—Comparison Between High Pressure, Hands Up, and High Pressure Emergency Air Brake Tests, Car No. 55 Loaded.

A comparison of the measured and theoretical distances is of interest. Referring to Fig. 71 the highest point on the west bound curve is for test No. D-24 (Table 5). For this point the initial speed was 25.5 m.p.h., the time 5.9 sec., the distance 134.9 ft. and the mean braking rate, 4.29 m.p.h.p.s. The theoretical distance based on a uniform braking rate is 110.5 ft. A similar computation for test No. D-26 (Table 5), the lower point on the curve gives 11.0 ft. in contrast to the measured distance of 17 1 2 ft.

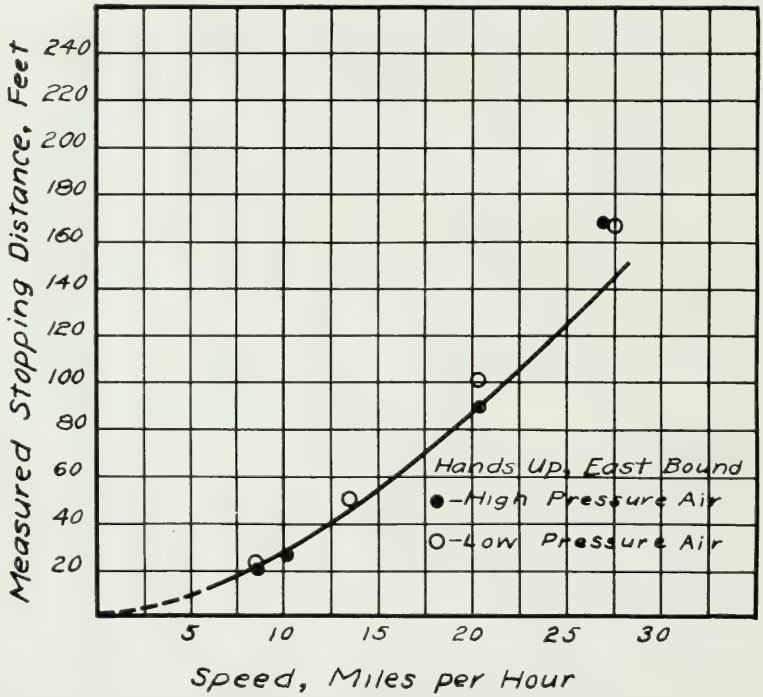


Fig. 76—High and Low Pressure Hands Up Air Brake Tests, Car No. 55 Lightly Loaded Relation Between Distance and Initial Speed.

Fig. 76 compares the results obtained with high and low air pressures with a light load on the car. A comparison of the braking action with light load and with full load on the car is shown in Fig. 77.

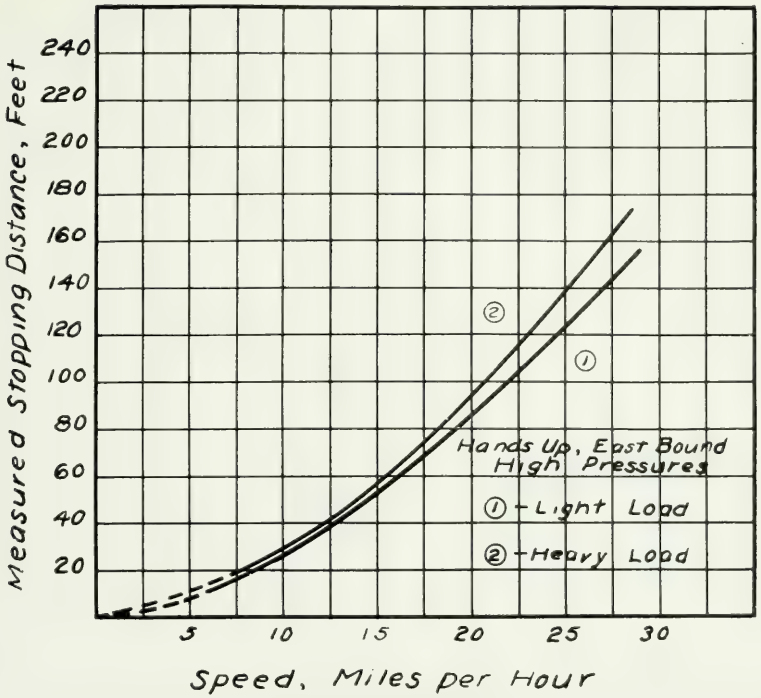


Fig. 77—Comparison Between, Loaded and Lightly Loaded Car Tests, Car No. 55

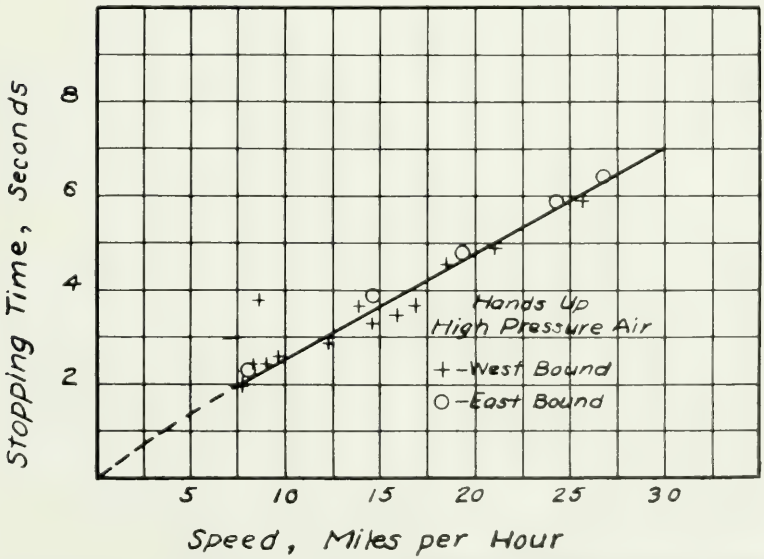


Fig. 78—High Pressure, Hands Up, Air Brake Tests, Car No. 55 Loaded. Relation Between Time and Initial Speed.

Stopping Time. An analysis of the relation between the interval of time required to bring the car to a stop and the initial speed has been made. Some of the curves resulting from this study are presented in Fig. 78, 79, 80, 81 and 82.

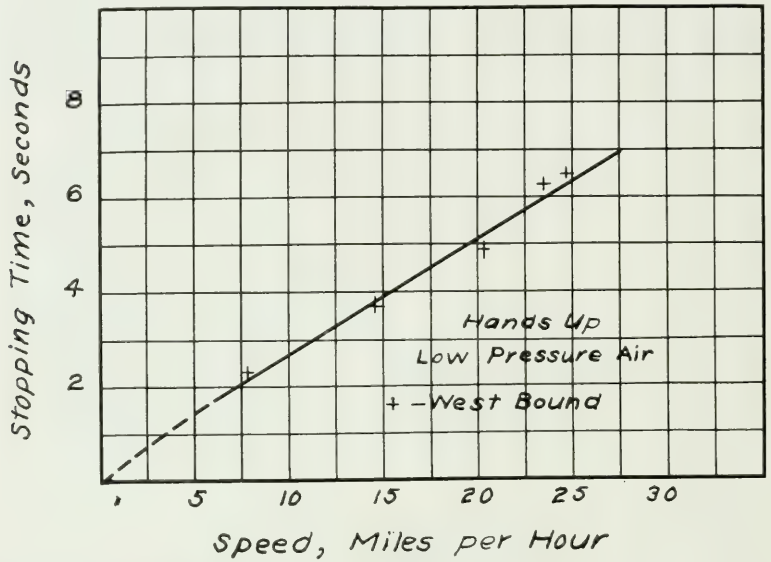


Fig. 79—Low Pressure, Hands Up, Air Brake Tests, Car No. 55 Loaded. Relation Between Time and Initial Speed.

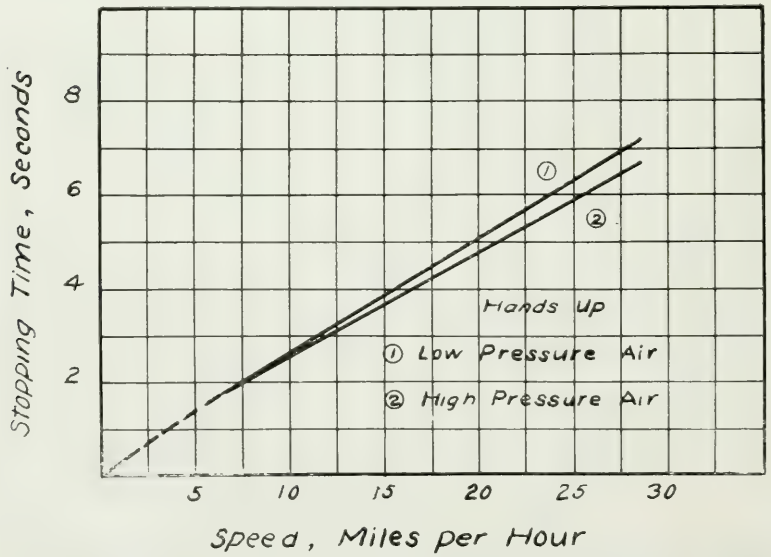


Fig. 80—Comparison Between High and Low Pressure, Hands Up, Air Brake Tests, Car No. 55 Loaded.

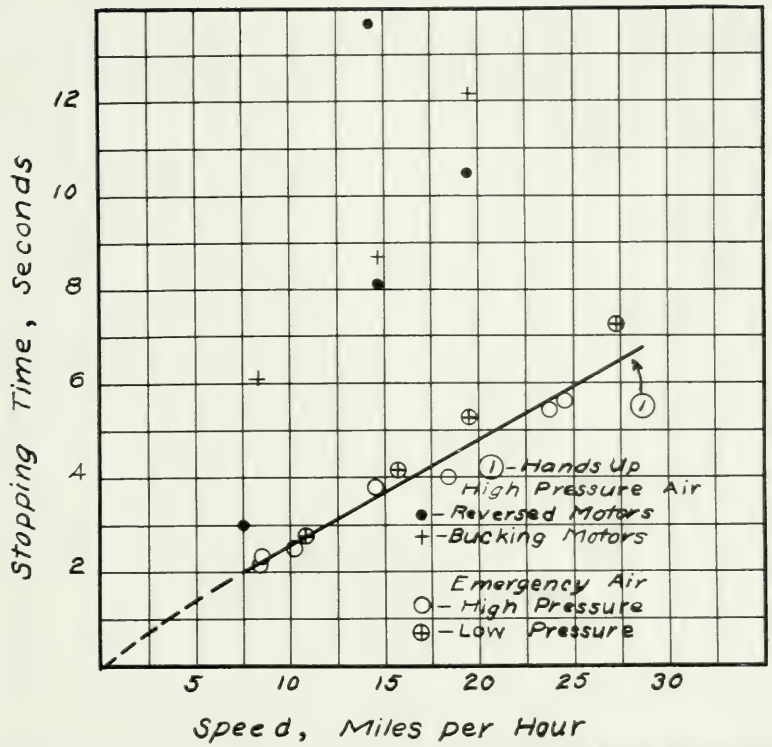


Fig. 81—Comparison of the Various Methods of Braking Car No. 55 Loaded. Relation Between Time and Initial Speed.

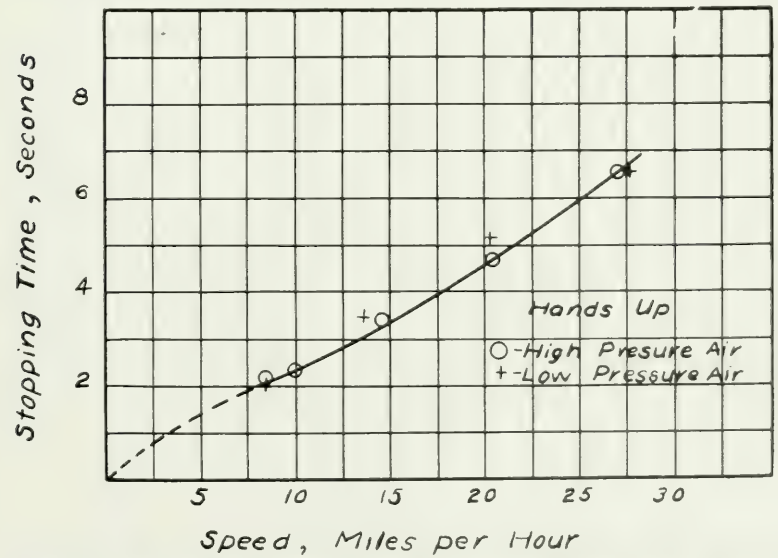


Fig. 82—High and Low Pressure. Hands Up. Air Brake Tests. Car No. 55 Lightly Loaded. Relation Between Time and Initial Speed.

The time interval used in drawing these curves was that recorded by the chronograph, Table 2-D, Appendix. Table 10-D, Appendix, contains a comparison of the stopping time as determined by several methods.

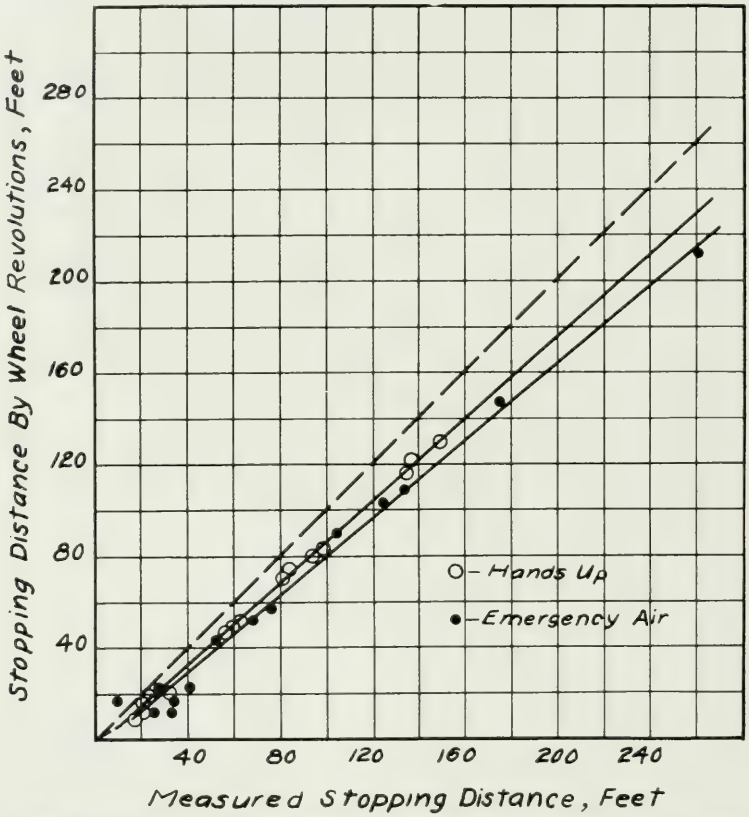


Fig. 83—A Comparison of the Stopping Distances as Determined by Two Methods Car No. 55 Loaded.

Comparison of Distance Measurements. A comparison of the stopping distances as determined by the tape and by the chronograph is shown in Fig. 83. The details pertaining to this comparison is shown in Table 9-D, Appendix. The circumference of the car wheel to which the contact maker was connected was 6.45 ft.

Distance-Time Curves. Data for the plotting of distance-time curves for those runs for which the chronograph records were complete are contained in Table 3-D, Appendix. Some typical runs are shown in Fig. 84.

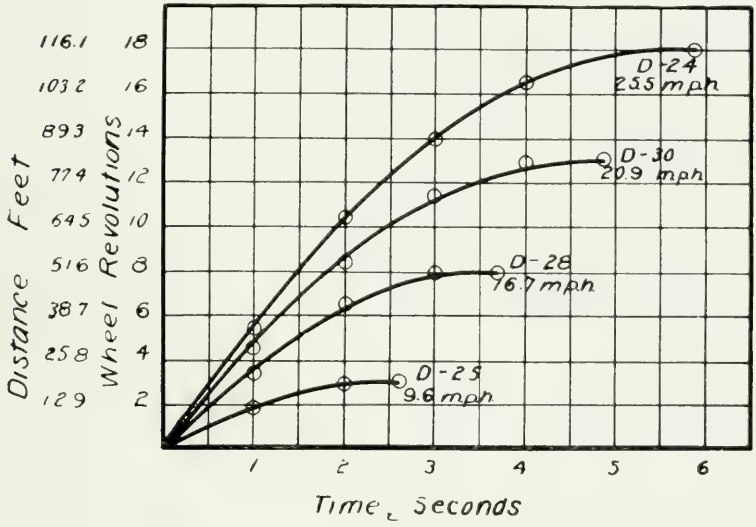


Fig. 84—Typical Distance-Time Curves, Car No. 55.

Analysis of a Distance-Time Curve. The distance-time curve for test No. D-39 has been plotted and analyzed in Fig. 85. The braking rates at different speeds for a number of other runs are tabulated in Table 8-D.

Brake Efficacy. As with the other cars the product of brake rigging efficiency and coefficient of shoe friction has been evaluated for two points of the braking rate curve Fig. 85. These points are those corresponding to the braking rates of 3.34 m.p.h. p.s. and 4.0 m.p.h.p.s. and to the speeds of 22.5 m.p.h. and 6.9. m.p.h. respectively. The corresponding values of the product are 0.0104 and 0.131.

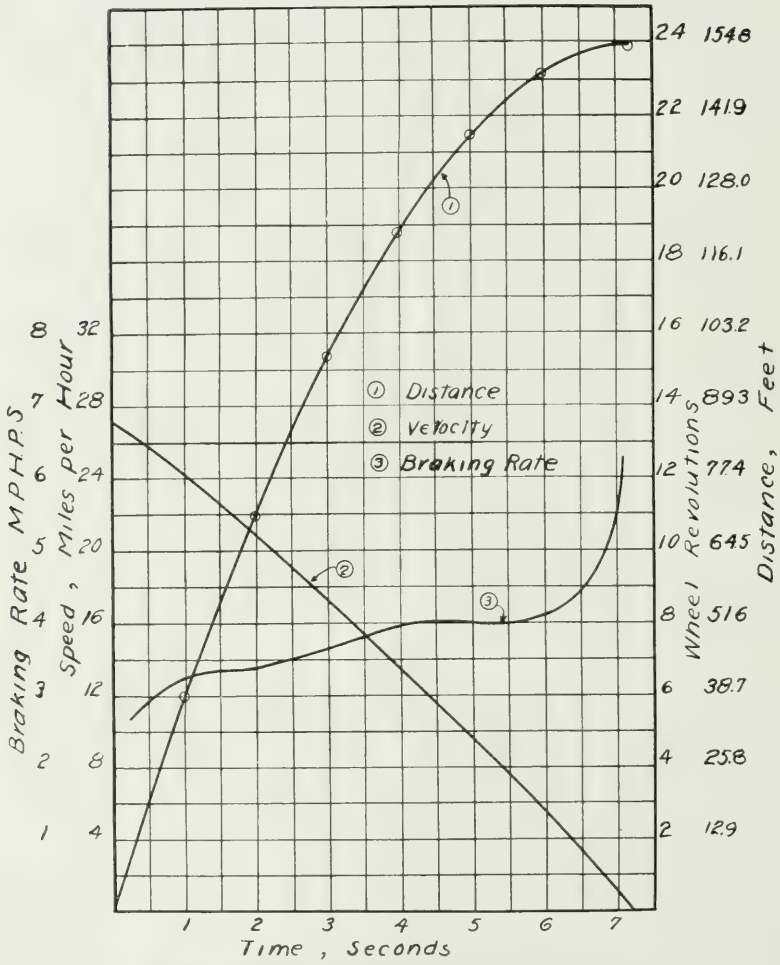
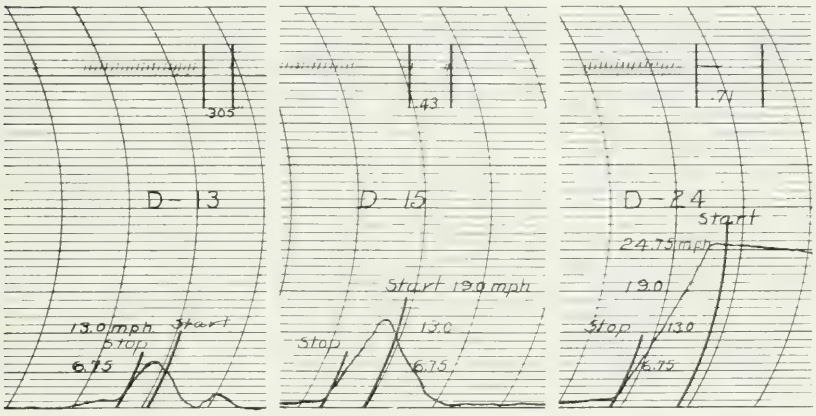

Braking Rate MPHPS
Speed, Miles per Hour
Wheel Revolutions
Distance, Feet
Time, Seconds
① Distance
② Velocity
③ Braking Rate
1 2 3 4 5 6 7
8 7 6 5 4 3 2 1
32 28 24 20 16 12 8 4
24 22 20 18 16 14 12 10 8 6 4 2
1548 1419 1280 1161 1032 893 774 645 516 387 258 129

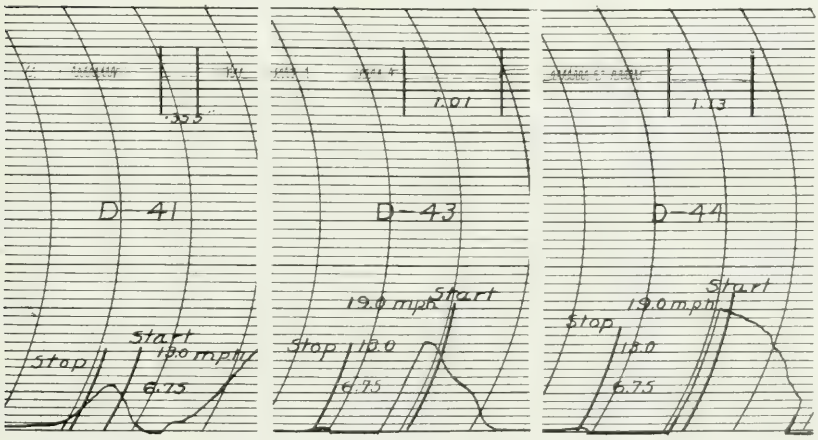
Fig. 85 —Analysis of a Distance-Time Curve, Car No. 55.

Speed Time Records.—Some typical speedmeter graphs are reproduced in Fig. 86, 87 and 88. These in a general way are similar to those shown for Car No. 61 and Car No. 244. In two of the reversed motor graphs the wheel to which the speed recorder was attached was driven backwards for a large part of the stopping time. The long interval of time necessary to secure braking action with bucking motors is well shown in Fig. 88. An analysis of this time interval for all of the tests on this car is contained in Table 7-D, Appendix, while Table 6-D contains an analysis of all of the speedmeter records. The calibration marked on the charts in Fig. 86, 87 and 88 was taken from Fig. 22.



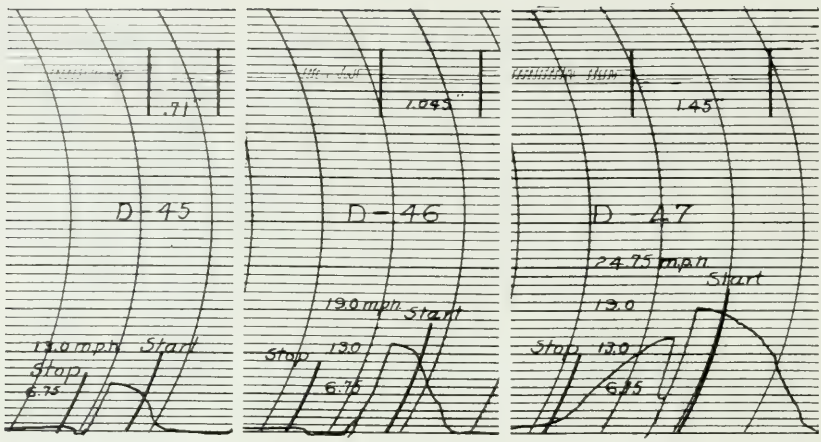
(a) (b) (c)

Fig. 86 –Speedmeter Records, Hands Up, Air Brake Tests, Car No. 55.



(a) (b) (c)

Fig. 87—Speedmeter Records, Reversed Motor Brake Tests, Car No. 55.



(a) (b) (c)

Fig. 88—Speedmeter Records, Bucking Motor Brake Tests, Car No. 55.

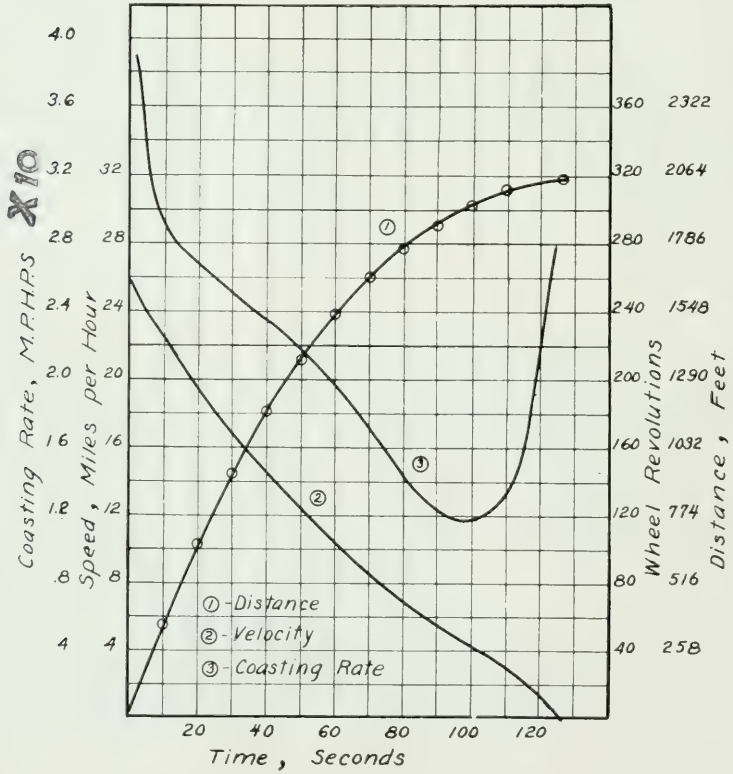


Fig. 89—Analysis of a Coasting Test, Car No. 55.

Coasting Test. The distance-time curve for the coasting test D-2 has been plotted in Fig. 89. From this curve were derived the speed-time and coasting rate curves shown in the same figure. The train resistance, in pounds per ton, for any speed may be found by multiplying the coasting rate in miles per hour per second at that speed by 91.1 and dividing the product by the weight of the car in tons.

The curves show that this car coasted a little over 2000 ft. from an initial speed of approximately 26 m.p.h.

SECTION IX

General Comments

It was pointed out in the preface that the fundamental object of the tests described in this bulletin was to determine the best way to stop an electric car in an emergency from which an accident might result. While an endeavor has been made to set forth all of the detail data of technical value that resulted from the tests it should be understood that the tests made were not complete tests where every detail of brake operation such as air consumption, electric energy consumption while braking electrically, etc., was observed. Such data as were necessary to answer the purpose of the tests were taken and in the course of the work a great mass of other data not immediately pertinent to the problem in hand were observed and recorded. It has been the aim to record here all material that was deemed of technical value, although, viewed from the standpoint of complete braking tests, the data are in many instances deficient.

The general conclusions and a brief summary of the test data were presented in Section I. Other details and discussions of tests on individual cars have been presented in the succeeding sections and in the Appendix. It has seemed worth while, however, to comment in a general way upon a certain features of the work.

Brake Shoe and Wheel Conditions. That the effectiveness of wheel brakes is dependent upon the wheel rim and shoe temperatures, shapes, and the materials from which they are made is well known to brake users and manufacturers. In these tests the cars were operated as they came from the properties to which they belong. No attempt was made to determine the effect of shoe and wheel contour changes or of the use of different kinds of shoes. On some of the cars both shoes and treads were badly worn, on others they were nearly new. Nor was there much uniformity in the matter of tread and shoe materials. No observations were taken of shoe and rim temperatures. Although each stop was an emergency stop the time between tests was sufficiently long that it is probable that the shoe and rim temperatures were very similar to those obtained in ordinary operation over city streets where frequent stops have to be made.

Checks on Speed and Distance Measurements. In the course of the tests on two of the cars, the cars were operated at balancing speed over a measured portion of the test track as a check upon the chronograph determinations of speed and distance. The time interval which elapsed while the car traversed the measured section was taken with a stop watch. The resulting data are as follows:

Run No. C-1
Measured distance—1200 ft.
Distance by the chronograph—1212 ft.
Time, stop watch—23.1 sec.
Time, chronograph 23.5.
Speed, by stop watch and measured distance—35.4 m.p.h.
Speed, by chronograph—35.2

Run No. D-1
Measured Distance—1000 ft.
Distance by chronograph—993 ft.
Time, stop watch—21.6
Time, chronograph—21.9
Speed, by stop watch and measured distance—31.5 m.p.h.
Speed, by chronograph—30.9 m.p.h.

The observed data and calculated results are seen to lie within the limits of personal error of the stop watch and chronograph operators.

Coasting Tests. Coasting tests were made on three of the cars and a distance-time curve for test D-2 on the Birney car is shown in Fig. 89. This car, starting at an initial speed of 25.9 m.p.h., coasted 2025 ft. by chronograph measurement, west bound. There was a light breeze blowing from the west which probably shortened the coasting distance somewhat. In the east bound test D-3 the car coasted 2676 ft. from an initial speed of 27.6 m.p.h. This distance was measured by the chronograph. In this test the number of poles along the track were counted, there being 27 pole spans traversed during the coasting period. A number of check measurements showed that poles were spaced almost exactly 100 ft. apart. The chronograph record for test D-4, also east bound, was defective, but a pole count gave a distance of 2850 ft. The initial speed was also 27.6 m.p.h.

On east bound run C-22 on Car No. 1026 the coasting distance was 2405 ft. from an initial speed of 27.4. There was a very light breeze from the southwest. A westbound run on the same car, test No. 32, starting with an initial speed of 29.2 m.p.h. gave a coasting distance of 3376 ft.

Test No. 35 on Car No. 244 gave a coasting distance of 3393 ft., west bound, from an initial speed of 28 m.p.h. In this test there was a slight breeze from the northwest.

Train resistance data calculated from these tests are shown in Fig. 26, 27 and 28.

Analysis of Time-Speed Curves. In sections V, VI, VII and VIII the relation between stopping time and initial speed was shown graphically. All of these curves as well as the distance-speed curves were extrapolated to the origin of coordinates of the curve sheet, the extrapolated portion of the curves being dashed instead of full lines. At first thought it would seem that all such curves should pass through the origin of coordinates and in order to compare the shape of the curves for the various cars

with the theoretical curves, Fig. 23 and Fig. 24 they were so drawn.

There is, however, a certain time interval dependent in magnitude upon the type of equipment, method of braking and motorman which is independent of the initial speed at which braking is commenced. A study of this time interval was made by extrapolating the curves in the direction of their trend until they intersected the vertical axis of the curve sheet. The results for the various cars were as follows, the time interval shown being the intercept between the origin and the intersection with the vertical axis:

	Time Interval, Seconds
Car No. 61	
Automatic air, mean of both directions	0.00
Straight and automatic air	1.10
Bucking motors	3.20
Car No. 244	
Low pressure air	0.70
High pressure air	1.25
Bucking motors	3.00
Car No. 1026	
High Pressure air	0.50
Low pressure air	0.50
Air and reversed motors	0.50
Bucking motors	3.50
Car No. 55	
Hands up, braking	0.25
High pressure air	0.35
Low pressure air	0.25

It was not possible to draw a reasonable time-speed curve for all kinds of braking on every car so the above tabulation is not complete. Also it will be noted that the results are not at all consistent. The main value of study being that it does show that such a time element is present and that in many cases it is a determinable quantity.

Brake Cylinder Pressure Lag. Some time must elapse from the operation of the brake valve handle until the pressure in the brake cylinder reaches approximately its full value. This time element has been discussed in the sections devoted to the individual cars and the data are tabulated in the Appendix. Tables 5-A, 5-B, 5-C and 5-D.

The mean values of this element for the different tests are here summarized in Table 20.

The magnitude of this time element is very important from the standpoint of the distance covered in making a stop since during the major portion of this time interval the car is traveling at the speed prevailing at the time the brake valve is thrown.

TABLE 20
Brake Cylinder Pressure Lag

Item	Time from the Stop Indication Until the Pressure Reached Approximately Full Value. Seconds			
Car. No.	61	244	1026	55
Automatic Air	3.44			1.19
Straight and Automatic Air	4.55			
Reversed Motors and Automatic Air	3.35			
Straight Air	4.22	1.79	1.02	
Reversed Motors and Straight Air		1.70	1.05	
Hands up				.96

The magnitude of this interval depends largely on the type of emergency valve (except with straight air) and the condition and size of the piping connecting the reservoir and the brake cylinder. These factors are partly within the control of the car builder and partly within that of the operating company. For quick braking this time interval must be kept down to its minimum value.

Time Lag Between Stop Indication and the Beginning of Retardation. It was pointed out in connection with the analysis of the speedmeter records for the various cars that there was a time interval between the stop indication and the beginning of retardation. It will be remembered that with the air brake tests this stop indication was made automatically in the time circuit of the chronograph and in the purely electrical braking tests the indication was made on the charts by the manipulation of a switch by the chronograph operator, the operator giving the indication at the report of the gun.

TABLE 21
The Time Lag Between the Stop Indication and the Beginning of Retardation

Item	Time from the Stop Indication to the Beginning of Retardation, Seconds			
Car No.	61	244	1026	55
Automatic Air	1.08			1.08
Straight and Automatic Air	1.54			
Straight Air	1,67	.91	1.48	
Reversed Motors	.44	1.00	1.54	.88
Bucking Motors	.39	.71	1.83	2.85
Reversed Motors Plus Emergency Air	1.02	.43	1.39	
Hands Up				.84

The fact that the stop indication was made differently in the electrical and air tests must be remembered when studying Table 21 in which the mean values of this time lag are summarized from Tables 7-A, 7-B, 7-C and 7-D, Appendix.

APPENDIX

APPENDIX

I. Description of Tables

This appendix is devoted to a presentation of tables of observed and derived test data. The arrangement of the tables is such as to permit their ready identification both as to car and as to comparative contents. All tables of data taken and derived in connection with Car No. 61 are listed in Section A, Car No. 244 in Section B, Car No. 1026 in Section C and Car No. 55 in Section D. The numerals in the table numbers refer to similar tables in the several sections.

In the following paragraphs a brief description of and some comment is presented on each kind of table.

Tables 1-A, 1-B, 1-C and 1-D. These tables are copies of the original test data, the arrangement of the log sheets being changed somewhat to facilitate typing. The approximate speed in miles per hour was read from the speedmeter. The number of wheel revolutions was that read on the electric counter. The time column contains the time to bring the car to a stop as determined by observers with stop watches. The several air pressures recorded are gauge readings taken when the car had come to a standstill. The measured distance is that measured along the track with the steel tape. On all cars except No. 61 the travel was that measured after the car had come to a standstill. On car No. 61 the travel is that indicated by a device connected to the piston rod in such a way that maximum piston travel was recorded.

In addition to the loads shown in the log sheet a dead load of about 300 pounds, representing the weight of the instruments was carried on each car.

In the several tables the kinds of brakes are indicated by the following symbols.

A.—Automatic air, emergency and sand.
S. & A.—Straight and automatic air, emergency and sand.
E.—Straight air, emergency and sand.
Hands Up—Dead man handle action on the safety car.
R.M.—Reversed Motors.
B.M.—Bucking Motors.
R.M.+A. and R.M.+E.—Reversed motors and emergency air and sand.

Tables 2-A, 2-B, 2-C, and 2-D. Data derived from an analysis of the chronograph records are recorded in these tables. The speeds and times shown are those used in plotting the curves and are considered the correct values of these items for the tests. The column headed "Revolutions B.V. to Stop" contains the number of car wheel revolutions for each run from the closing

of the brake valve contact to the stop. The corresponding distance is that obtained by multiplying the wheel revolutions by the wheel circumference.

The average braking rate is that obtained by dividing the speed in miles per hour by the time in seconds required to bring the car to a standstill.

Tables 3-A, 3-B, 3-C, and 3-D. In these tables the total number of wheel revolutions made up to the end of the first, second, third, etc., seconds are recorded for such of the chronograph records as were complete. The tables give a graphic picture of the time necessary to bring the car to a stop at different speeds.

Tables 4-A, 4-B, 4-C, and 4-D. These tables contain data derived from an analysis of the trainagraph records. The time is that measured on the record, beginning with the operation of the brake valve contact and ending with the stop indication marked by the time pen. The "Maximum Brake Cylinder Pressure" was the highest pressure reached during braking as determined from the trainagraph indicator attached to the brake cylinder. The minimum pressure recorded in the table was the lowest value reached after the maximum had been passed. Of course, at the instant the brake valve was operated the brake cylinder pressure was zero. The average brake cylinder pressure recorded in the table is the arithmetical average of the minimum and maximum and is not the integrated average of the pressure curve recorded on the trainagraph chart.

Tables 5-A, 5-B, 5-C and 5-D. When the brake valve was thrown the pressure in the brake cylinder did not reach its maximum value instantaneously. In these tables a study has been made of the time elements involved in the growth of pressure in the brake cylinder and the decay of pressure in the air system connected therewith. With the automatic equipment on car No. 61 a decided "knee" was reached in the pressure curve some little time before the pressure attained its maximum value. The time from the operation of the brake valve contact until the pressure reached the knee is analyzed in Table 5-A.

Tables 6A, 6-B, 6-C and 6-D. A study of the speedmeter records resulted in the data tabulated under these headings. The speed data in miles per hour were read from the chart using the predetermined calibration of the speedmeter. These data were then used in connection with the correct speeds as determined from the chronograph record in plotting the speedmeter calibration curves shown in the report. In the column headed "Time from B.V. to Retardation" the time which elapsed from the instant of brake valve contact operation to the beginning of retardation is shown. The beginning of retardation was determined by the point on the speedmeter chart at which the speed started to decrease.

Tables 7-A, 7-B, 7-C and 7-D. The time interval discussed in the last sentence has been further analyzed in Tables 7-A, 7-B,

7-C and 7-D by dividing the test runs into groups, the grouping being based on the kind of braking.

Tables 8-A, 8-B, 8-C and 8-D. Braking rates in miles per hour per second at several different speeds were calculated for a number of the runs on each car. The speeds and time interval necessary for these calculations were taken from the chronograph records.

Tables 9-A, 9-B, 9-C and 9-D. In these tables the distance covered in bringing the car to a full stop as determined by several methods is analyzed. In comparing these data it is to be remembered:

(1) That the measured distance was that measured with a tape line from the shot mark on the track to the point as determined on the track by the line of sight along the gun, where the car stopped.

(2) The distance determined by the revolution counter was the distance rolled over by the car wheel from the time the gun was fired until the car stopped.

(3) The distance determined from the chronograph record is that rolled over by the car wheel after the operation of the brake valve contact.

Tables 10-A, 10-B, 10-C, and 10-D. The time interval involved in making the stops as determined by the several records and stop watch readings is shown in these tables. As the chronograph clock circuit marked the time in all of the records the time as determined from the speedmeter and trainagraph records is valuable only as a check and to determine the constancy of the speed at which their record charts were driven.

Tables 11-A and 11-B. In the tests on Cars No. 61 and 244 a variation in pressure in the brake cylinder occurred about the time the car came to a full stop. These tables show the correlation between the time as measured from the instant of the brake valve contact operation to the stop indication and that measured from the instant of brake valve operation to the instant at which the brake cylinder pressure changed. The change in brake cylinder pressure is shown also.

APPENDIX

SECTION A

TABLE 1-A

TEST LOG INTERURBAN CAR NO. 61

Observers:
Chronograph—C. W. Melephant
Trainagraph—H. Wood, P. B. McGinnis
Speedmeter—M Aldrich
Motorman—Frank White
Recorder—W. E. Blowers
Time and Revolution Record—W. L. Galey
Gunman—C. H. Clark

Date—May 15, 1923
Place—Pettigrew Substation
Weather—Cloudy and occasional Sprinkles
Wind—Southwest Breeze

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Piston Travel at End of Run Inches	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
A-1	16.0	14	7.0	70.5	60	137.0	5.375	A.	26	West	A.M.	Dry Track
A-2	20.8	22	8.4	70.0	59	210.3	5.625	A.	26	West	A.M.	Dry Track
A-3	24.5	33	10.4 11.0	70.0	58	309.1	5.875	A.	26	West	A.M.	Dry Track
A-4	28.8	45	12.3 13.0	70.0	58	427.7	5.750	A.	26	West	A.M.	Dry Track
A-5	32.5	52	13.4 14.0	70.0	57	475.8	5.750	A.	26	West	A.M	Dry Track
A-6	38.4	70	16.4 16.4	70.0	57	672.6	5 875	A.	26	West	A.M.	Dry Track
A-7	23.0	29	9.0 9.8	71.0	57	261.2	5.500	A.	26	East	P.M.	Dry Track
A-8	30.0	47	13.4	71.0	57	440.6	5.250	A.	26	East	P.M.	Dry Track
A-9	20.8	23	8.5 9.0	71.0	58	223.5	5.375	A.	26	East	P.M.	Damp Track
A-10	36.0	65	15.6	71.0	68	605.4	6.750	S. & A.	26	East	P.M.	Rain
A-11	20.0	26	9.6 9.5	71.0	69	247.6	6.125	S. & A.	26	East	P.M.	Rain
A-12	12.0	9	5.3 5.5	----	--	78.0	5.500	S. & A.	26	East	P.M.	Dry Track
A-13	16.5	14	7.0 7.0	71.0	58	131.7	5.125	A.	26	East	P.M.	Dry Track
A-14	40.0	81	17.5	70.0	70	746.2	6.500	S. & A.	26	East	P.M.	Dry Track
A-15	35.2	66	15.6 15.3	70.0	70	636.1	6.625	S.	26	East	P.M.	Dry Track
A-16	11.2	4	----	---	--	63.0	-----	R.M.	26	East	P.M.	Dry Track. Two Points on Controller

A-17	12.0	4	5 4 5 6			64.5		R.M.	26	East	P.M.	Dry Track. Two Points on Controller
A-18	15.0	12	10.0 10.0			141.6		B.M.	26	East	P.M.	Dry Track. One Point on Controller Reverse. (Circuit Breaker Thrown by Hand)
A-19	12.0	7	11 0		--	91.8		B.M.	26	East	P.M.	Dry Track. Reverse Only Thrown
A-20	20.0	18	20.0		--	270.5		B.M.	26	East	P.M.	Dry Track. Reverse Only Thrown
A-21	25.0	10	13.8 14 5		--	335.0		R.M.	26	East	P.M.	Dry Track. Two Points on Controller
A-22	20.0	15	9 2 9 0			201.8		R.M.	26	East	P.M.	Dry Track. Two Points on Controller
A-23	28.0	18	16 1 16 2			489.6		R.M	26	East	P.M.	Dry Track Two Points on Controller
A-24	30.0	72	22.8 21.3			580.3		B.M.	26	East	P.M.	Dry Track. Reverse Only Thrown
A-25	34.0	62	19.2			623.6		B.M.	26	East	P.M.	Dry Track. Reverse Only Thrown
A-26	32.5	10	17.8 18 2	70.0	57	609.3	5.250	R.M.+A.	21	East	P.M.	Two Points on Controller 1.75 In. Flat Spot on Wheels
A-27	22.4	5	10.0	70.0	58	274.3	4.875	R.M.+A.	21	East	P.M.	Two Points on Controller. 1.25 In. Flat Spot on Wheels
A-28	14.0	4	5.3 5 4	70.0	57	103.0	5.000	R.M.+A.	21	East	P.M.	Two Points on Controller
A-29	36.8	83	6.0 20.0 20.2	50.0	49	795.0	4.750	S & A.	21	East	P.M.	Reduced Pressure

TABLE 2-A
INTERURBAN CAR NO. 61
Analysis of the Chronograph Records

Run No.	Speed M.P.H.	Stop Time Sec.	B.V. to Stop Revolutions	Stop Distance Feet	Average Braking Rate M.P.H. P.S.
A-1	20.0	6.5	13.0	121.1	3.09
A-2	27.1	8.4	20.5	191.0	3.20
A-3	30.6	10.8	32.0	298.1	2.82
A-4	37.0	12.8	43.0	410.0	2.90
A-5	39.4	13.9	49.5	466.0	2.83
A-6	45.3	16.6	69.0	643.0	2.74
A-7	26.2	9.2	27.0	251.8	2.85
A-8	39.2	12.6	47.0	437.0	3.12
A-9	28.0	8.6	22.5	209.8	3.25
A-10	41.7	15.6	62.0	577.0	2.66
A-11	25.3	9.8	25.0	232.8	2.57
A-12	12.7	5.5	7.5	69.9	2.33
A-13	18.5	7.1	13.5	125.8	2.61
A-14	48.9	17.6	Bad Record		2.78
A-15	46.9	15.8	Bad Record		2.97
A-16	14.5	5.5	Slip		2.64
A-17	12.1	5.4	Slip		2.23
A-18	18.6	10.3	Bad Record		1.79
A-19	14.3	11.3	Slip		1.27
A-20	27.8	19.1	Erratic		1.46
A-21	34.2	14.8	Erratic		2.32
A-22	26.9	9.3	Erratic		2.90
A-23	34.6	16.4	Erratic		2.12
A-24	36.7	21.0	Erratic		1.75
A-25	41.5	19.8	Erratic		2.10
A-26	39.5	18.4	Erratic		2.14
A-27	29.9	10.2	Erratic		2.94
A-28	16.4	5.7	Erratic		2.90
A-29	41.8	20.1	Erratic		2.09

TABLE 3-A

INTERURBAN CAR NO. 61

Analysis of Wheel Revolutions and Time from the Chronograph Records

Run No.	Speed M.P.H.	Total Revolutions at End of Seconds:															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A-1	20.0	3.0	6.0	8.5	10.5	12.0	12.5										
A-2	27.1	4.0	7.5	11.5	14.0	17.0	18.5	20.0									
A-3	30.6	5.0	10.0	14.5	18.5	22.0	25.0	27.5	29.5	31.0	32.0						
A-4	37.0	6.0	11.5	16.5	21.5	26.0	30.0	33.5	36.0	38.5	41.0	42.5	43.0				
A-5	39.4	6.0	12.0	17.0	22.0	27.0	31.0	35.0	38.5	41.5	44.0	46.0	47.5	48.5			
A-6	45.3	7.0	14.0	21.0	27.0	32.0	38.5	43.5	48.5	52.5	56.5	60.0	63.0	65.5	67.0	68.5	69.0
A-13	18.5	3.0	6.0	8.5	10.5	12.0	12.5	13.0									
A-7	26.2	4.0	8.0	11.0	14.5	17.0	20.0	22.0	23.5	25.0							
A-9	28.0	4.0	7.5	11.5	14.5	17.0	19.5	21.0	22.0								
A-8	39.2	6.0	11.5	16.5	21.5	25.5	30.0	33.5	36.5	39.5	41.5	43.0	44.0				
A-12	12.7	2.0	4.0	6.0	7.0	7.5											
A-11	25.3	4.0	8.0	11.5	15.0	18.0	20.5	22.5	24.0	24.5							
A-10	41.7	7.0	13.5	19.0	25.0	30.0	35.0	39.5	43.5	48.5	52.0	54.5	57.0	59.0	60.0	60.5	

NOTE. — One revolution of the car wheel equals 9.31 ft.

TABLE 4-A
INTERURBAN CAR NO. 61
Analysis of the Trainagraph Record

Run No.	Time B.V. to Stop Sec.	Brake Cyl. Max. Press. Lb. Per Sq. In.	Brake Cyl. Min. Press. Lb. Per Sq. In.	Brake Cyl. Avg. Press. Lb. Per Sq. In.	Brake Pipe Max. Press. Lb. Per Sq. In.	Kind of Braking
A-1	6.4	60.0	60.0	60.0	71.0	A.
A-2	8.4	59.0	59.0	59.0	70.0	A.
A-3	10.0	59.0	59.0	59.0	70.0	A.
A-4	12.8	60.0	60.0	60.0	70.0	A.
A-5	13.9	59.0	59.0	59.0	70.0	A.
A-6	16.2	60.0	60.0	60.0	70.0	A.
A-7	9.8	60.0	60.0	60.0	70.0	A.
A-8	12.9	60.0	60.0	60.0	70.0	A.
A-9	8.8	60.0	60.0	60.0	70.0	A.
A-10	14.8	71.0	71.0	71.0	70.0	S. & A.
A-11	9.7	69.0	69.0	69.0	69.5	S. & A.
A-12	5.4	72.0	72.0	72.0	70.0	S. & A.
A-13	6.9	59.0	59.0	59.0	69.5	A.
A-14	15.9	70.0	70.0	70.0	69.5	S. & A.
A-15	15.7	70.0	70.0	70.0	70.0	S
A-26	18.7	58.5	58.5	58.5	69.0	R.M. + A.
A-27	10.0	60.0	60.0	60.0	69.0	R.M. + A.
A-28	6.3	60.0	60.0	60.0	70.0	R.M. + A.
A-29	19.4	50.0	50.0	50.0	49.0	S. & A.

TABLE 5-A
INTERURBAN CAR NO. 61
Analysis of Time Data from the Trainagraph Record

Run No.	Time B.V. to Max. Press. in B.C. Sec.	Time from B.V. to Knee of Curve for B.C. Press. Sec.	Time from Max. to Min. Press. in B.P.
A-1	3.94	3.33	1.60
A-2	4.88	3.33	2.02
A-3	6.67	3.66	2.04
A-4	9.11	3.44	2.11
A-5	9.11	3.33	2.11
A-6	9.11	3.66	2.04
A-7	8.66	3.77	2.85
A-8	6.72	3.76	2.28
A-9	8.68	3.76	1.83
A-10	8.77	4.67	1.83
A-11	9.57	5.24	2.00
A-12	8.32	4.56	1.83
A-13	5.47	3.76	1.88
A-14	9.12	4.22	2.28
A-15	8.54	4.22	1.96
A-26	5.70	3.46	1.85
A-27	4.68	3.16	1.82
A-28	5.37	3.46	1.96
A-29	6.96	3.46	1.85

Average Time for Brake Cylinder Press. to Reach Maximum:
Automatic Air ..... 6.57 Sec.
Straight and Automatic Air ..... 9.00 Sec.
Reversed Motors Plus Automatic Air ..... 5.25 Sec.

Average Time for Brake Cylinder Press. Curve to Reach Knee:
Automatic Air ..... 3.44 Sec.
Straight and Automatic Air ..... 4.55 Sec.
Reversed Motors Plus Automatic Air ..... 3.35 Sec.

Average Time for Brake Pipe Press. to Reach Minimum:
Automatic Air ..... 2.07 Sec.
Straight and Automatic Air ..... 1.99 Sec.
Reversed Motors Plus Automatic Air ..... 1.88 Sec.

TABLE 6-A.
INTERURBAN CAR NO. 61
Analysis of the Speedmeter Record

Run No.	Speed M.P.H.	Stop Time Seconds	Time from B.V. to Retardation Seconds	Kind of Braking
A-1	16.0	6.8	.48	A.
A-2	20.8	8.1	1.65	A.
A-3	24.8	10.0	1.55	A.
A-4	29.8	11.4	1.42	A.
A-5	32.0	13,9	1.39	A.
A-6	39.3	16.6	0.00	A.
A-7	23.0	10.0	1.86	A.
A-8	30.0	13.1	.88	A.
A-9	20.6	8.7	1.05	A.
A-10	35.6	15.4	1.60	S. & A.
A-11	20.0	8.7	1.81	S. & A.
A-12	12.0	5.6	1.40	S. & A.
A-13	16.5	6.4	.44	A.
A-14	39.6	15.9	1.34	S. & A.
A-15	35.6	15.1	1.67	S.
A-16	11.2	4.3	.36	R.M.
A-17	12.0	4.9	.36	R.M.
A-18	15.2	9.3	.00	B.M.
A-19	12.0	11.7	.00	B.M.
A-20	20,0	19.5	.37	B.M.
A-21	25.0	15.5	.56	R.M.
A-22	20.8	8.4	.34	R.M.
A-23	28.0	19.1	.58	R.M.
A-24	29.5	19.7	.77	B.M.
A-25	34.0	19.3	.80	B.M.
A-26	32.5	18.6	1.09	R.M. + A.
A-27	23.0	10.6	1.18	R.M. + A.
A-28	14.0	5.7	.78	R.M. + A.
A-29	36.8	20.6	1.89	S. & A.

TABLE 7-A
INTERURBAN CAR NO. 61
Analysis of the Time from the Stop Indication to the Beginning of Retardation

Run No.	Kind of Braking	Time from B.V. to Retardation Seconds
A-1	A.	.47
A-2	A.	1.65
A-3	A.	1.55
A-4	A.	1.42
A-5	A.	1.39
A-6	A.	.00
Average		1.08
A-13	A.	.43
A-7	A.	1.86
A-9	A.	1.5
A-8	A.	.88
Average		1.06
A-12	S. & A.	1.40
A-11	S. & A.	1.81
A-10	S. & A.	1.60
A-14	S. & A.	1.34
Average		1.54

Run No.	Kind of Braking	Time from B.V. to Retardation Seconds
A-29	S. & A.	1.89
A-15	S.	1.67
A-17	R.M.	.36
A-16	R.M.	.36
A-22	R.M.	.34
A-21	R.M.	.56
A-23	R.M.	.58
Average		.44
A-19	B.M.	.00
A-18	B.M.	.00
A-20	B.M.	.37
A-24	B.M.	.77
A-25	B.M.	.80
Average		.39
A-28	R.M. + A.	.78
A-27	R.M. + A.	1.18
A-26	R.M. + A.	1.09
Average		1.02

TABLE 8-A
INTERURBAN CAR NO. 61
Braking Rates at Different Speeds

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.	Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
A-1	19.5	1.02	A-7	24.4	4.08
	16.2	3.33		20.2	3.37
	10.9	4.38		15.7	4.01
	4.0	4.02		10.5	4.90
				3.9	3.29
A-2	25.3	1.02			
	22.1	3.39			
	17.2	3.43	A-9	26.5	.78
	11.5	4.05		22.9	3.48
	4.2	3.98		17.7	3.88
				11.7	3.37
A-3	30.2	1.48		4.5	3.84
	25.7	3.14			
	20.2	2.99			
	12.4	3.08	A-11	23.9	1.29
	9.4	4.60		20.0	2.56
	3.3	3.48		14.4	3.20
				9.8	3.98
A-4	36.4	1.45		3.9	3.79
	30.2	3.08			
	24.0	3.41			
	17.1	3.04	A-13	17.8	1.21
	11.5	4.18		13.5	2.73
	3.9	3.79		7.9	3.82
				2.5	3.57
A-5	36.4	1.84			
	30.8	2.42			
	24.7	2.33	A-15	13.8	.84
	17.6	3.79		12.2	2.04
	11.2	2.91		8.9	3.24
	4.4	3.74		3.4	3.83

TABLE 9-A
INTERURBAN CAR NO. 61
Comparisons of Stopping Distances as Determined by Several Methods

Run No.	Measured Distance Feet	Distance by Chronograph		Distance by Revolution Counter		Kind of Braking
		Revolution of Car Wheel	Distance Feet	Revolution of Car Wheel	Distance Feet	
A-1	137.0	13.0	121.1	14	130.2	A.
A-2	210.0	20.5	191.0	22	204.8	A.
A-3	309.1	32.0	298.1	33	307.0	A.
A-4	427.7	43.0	410.0	45	419.0	A.
A-5	475.8	49.5	466.0	52	484.0	A.
A-6	672.6	69.0	643.0	70	652.0	A.
A-7	261.2	27.0	251.8	29	270.0	A.
A-8	440.6	47.0	437.0	47	437.0	A.
A-9	223.5	22.5	209.8	23	214.0	A.
A-13	131.7	13.5	125.8	14	130.2	A.
A-10	605.4	62.0	577.0	65	605.1	S. & A.
A-11	247.6	25.0	232.8	26	242.0	S. & A.
A-12	78.0	7.5	69.9	9	83.4	S. & A.
A-14	746.2	----	-----	81	754.0	S. & A.
A-29	795.0			83	773.0	S. & A.
A-26	609.3			10	93.1	R.M. + A.
A-27	274.3			5	46.5	R.M. + A.
A-28	103.0			4	37.3	R.M. + A.

TABLE 10-A
INTERURBAN CAR NO. 61
Comparison of Stopping Time in Seconds as Determined by Several Methods

Run No.	Chrono-graph	Stop Watch	Traina-graph	Speed Meter	Kind of Braking
A-1	6.5	7.0	6.4	6.8	A.
A-2	8.4	8.4	8.4	8.1	A.
A-3	10.8	10.7	10.0	10.0	A.
A-4	12.8	12.6	12.8	11.4	A.
A-5	13.9	13.8	13.9	13.9	A.
A-6	16.6	16.4	16.2	16.6	A.
A-7	9.2	9.4	9.8	10.4	A.
A-8	12.6	13.4	12.9	13.1	A.
A-9	8.6	8.8	8.8	8.7	A.
A-13	7.1	7.0	6.9	6.4	A.
A-10	15.6	15.6	14.8	15.4	S. & A.
A-11	9.8	9.6	9.7	8.7	S. & A.
A-12	5.5	5.4	5.4	5.6	S. & A.
A-14	17.6	17.5	15.9	15.9	S. & A.
A-29	20.0	20.1	19.4	20.6	S. & A.
A-16	5.5			4.3	R.M.
A-17	5.4	5.5		4.9	R.M.
A-21	14.8	14.2		15.5	R.M.
A-22	9.3	9.1		8.4	R.M.
A-23	16.4	16.2		19.1	R.M.
A-18	10.3	10.0		9.3	B.M.
A-19	11.3	11.0		11.7	B.M.
A-20	19.1	20.0		19.5	B.M.
A-24	21.0	22.1		19.7	B.M.
A-25	19.8	20.4		19.3	B.M.
A-26	18.4	18.0	18.7	18.6	R.M. +A.
A-27	10.2	10.0	10.0	10.6	R.M. +A.
A-28	5.7	5.4	6.3	5.7	R.M. +A.

TABLE 11-A
INTERURBAN CAR NO. 61
Comparison of Stopping Times as Determined From the Trainagraph Record

Run No.	Stop Time B.V. to Stop Sec.	Stop Time from Pressure Curve Sec.	Variation in Pressure at Stop Lb. Per Sq. In.
A-1	6.4	5.9	4.5
A-2	8.4	7.1	3.0
A-3	10.0	10.2	7.0
A-4	12.8	14.1	2.5
A-5	13.9	10.3	2.5
A-6	16.2	15.4	3.0
A-7	9.8	8.8	3.0
A-8	12.9	12.5	2.5
A-9	8.8	8.1	3.0
A-10	14.8	13.9	2.5
A-11	9.7	9.2	2.5
A-12	5.4	2.3	5.0
A-13	6.9	6.2	4.0
A-14	15.9	16.0	3.5
A-15	15.7	14.9	4.0
A-26	18.7	17.1	6.5
A-27	10.0	9.3	4.5
A-28	6.3	5.7	2.5
A-29	19.4	18.6	5.5

APPENDIX

SECTION B

TABLE 1-B

TEST LOG CITY CAR NO. 244

Observers:
Chronograph—C. W. Melephant
Trainagraph—H. Wood, P. B. McGinnis
Speedmeter—M. Aldrich
Motorman—Harry Coleman
Recorder—W. E. Blowers
Time and Revolution Record—W. L. Galey
Gunman—C. H. Clark

Date—May 16, 1923
Place—Pettigrew Substation
Weather—Cloudy with Occasional Sprinkles
Wind—Northwest Breeze

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Piston Travel at End of Run Inches	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
B-1	12.5	12	6.4	62.0	61.0	97.8	4.000	E	24	East	A.M.	Wet Track
B-2	9.0	6	4.8 5.0	62.0	52.0	56.2	- - -	E.	24	East	A.M	Wet Track
B-3	16.0	18	8.6 8.6	60.0	52.0	152.2	4.000	E.	24	East	A.M.	Wet Track
B-4	19.2	28	11.4	61.0	51.0	228.6		E.	24	East	A.M.	Wet Track
B-5	22.4	34	11.6 11.4	61.0	52.0	275.2	-	E	24	East	A.M	Dry Track
B-6	10.0	8	4.6 4.8	71.0	61.0	65.6	4.125	E.	24	East	P.M.	Dry Track
B-7	11.2	9	5.2	71.5	59.0	77.8	- - -	E.	24	East	A.M.	Dry Track
B-8	16.0	12	7.2 7.2	71.0	60.5	139.3		E.	24	East	A.M.	Few Drops of Rain
B-9	22.0	34	10.4 10.6	69.5	56.0	264.5		E.	23	East	A.M.	Few Drops of Rain
B-10	4.8	2	2.0 2.0	71.0	62.0	14.0		E.	23	East	A.M.	Few Drops of Rain
B-11	22.0	29	10.2 10.2	70.0	59.0	238.7		E.	21	West	P.M.	Few Drops of Rain
B-12	15.5	16	7.2 7.0	71.0	60.0	129.9	-	E.	21	West	P.M.	Few Drops of Rain
B-13	12.0	11	5.8 5.6	70.5	60.0	88.9	-	E.	21	West	P.M.	Few Drops of Rain
B-14	4.0	1	1.6 2.0 2.2	70.0	62.0	11.5		E.	22	West	P.M.	Few Drops of Rain
B-15	4.8	3	2.0 2.0 2.2	69.5	61.0	14.5	-	E.	20	West	P.M.	Few Drops of Rain

B-16	4.0	2	2 0 1 8	71 0	61 5	12 5	E.	20	West	P.M.	Dry Track
B-17	4.5	1	2 0 2 0 2 2			12.7	E.	20	West	P.M.	Dry Track
B-18	4 0	1	2 2	71 0	62 0	11.4	E.	20	West	P.M.	Dry Track
B-19	4 8	1	4 6 4 6			13.7	R.M.	20	West	P.M.	Dry Track. Two Points on Controller (Breaker Blew)
B-20	4 0	2	2 6 2 8 3 1			10 9	R.M.	20	West	P.M.	Dry Track. One Point on Controller
B-21	9.0	3	5 6 5 6			39 8	R.M.	20	West	P.M.	Dry Track. Two Points on Controller (Breaker Blew)
B-22	11.5	4	5 6 5 6			39 8	R.M.	20	West	P.M.	Dry Track. One Point on Controller
B-23	20 0	12	11 6 11 4			200 5	R.M.	22	West	P.M.	Dry Track. One Point on Controller
B-24	19.5	10	7 0 7 2			136 0	R.M.	20	West	P.M.	Dry Track. One Point on Controller
B-25	14 5	3	7 6 7 4			112 0	R.M.	18	West	P.M.	Dry Track. One Point on Controller
B-26	17.6	6	9 0 9 0 10 0			152 6	R.M.	17	West	P.M.	Dry Track. Two Points on Controller. (Breaker Blew)
B-27	18.0	14	11.6 11 4 11 2			219 7	B.M.	20	West	P.M.	Dry Track
B-28	14 0	11	9 8 11 0 9 8			165 0	B.M.	20	West	P.M.	Dry Track
B-29	8 5	3	7 4 8 2			70 6	B.M.	20	West	P.M.	Dry Track
B-30	4 8	3	6 0 5 8 5 8			24 8	B.M.	20	West	P.M.	Dry Track
B-31	9 0	3	4 6 4 4			65 0	E. + R.M.	19	West	P.M.	Dry Track. One Point on Controller. Air Last with Sand
B-32	12.0	4	7 0 7 4	70 5	64 0	120 0	E. + R.M.	19	West	P.M.	Dry Track. One Point on Controller. Air First with Sand. Threw Breaker to save Controller Due to Arc
B-33	23 0	7	10 4 10 6	69 0	60 0	293 0	E. + R.M.	20	West	P.M.	Dry Track. One Point on Controller. Air First, Sand Late
B-34	17 5	6	7 6 8 0	71 0	65 0	182 6	E. + R.M.	14	West	P.M.	Dry Track. One Point on Controller. One Inch Flat Spot on Wheel
B-35	22 4	422	169 4 169 6	—	—		Coasting Record	14	West	P.M.	Dry Track

TABLE 2-B
CITY CAR NO. 244
Analysis of the Chronograph Records

Run No.	Speed M.P.H.	Stop Time Sec.	Revolutions B.V. to Stop	Stop Distance Feet	Average Braking Rate M.P.H.P.S.
B-1	16.1	6.4	11.0	85.7	2.50
B-2	10.3	5.3	6.5	50.6	1.97
B-3	18.8	8.7			2.17
B-4	23.7	10.8	28.0	218.0	2.20
B-5	26.8	11.2	33.5	260.0	2.40
B-6		4.7	7.0	54.5	
B-7	14.2	4.8			2.98
B-8	21.3	7.2	16.0	124.5	2.98
B-9	28.8	10.4	31.0	241.5	2.77
B-10	5.7	2.8	1.5	11.7	2.00
B-11	27.2	10.0	29.0	225.5	2.70
B-12	19.7	6.9	14.0	109.0	2.86
B-13	16.7	5.5	9.5	74.0	3.04
B-14	5.1	1.9	1.0	7.8	2.54
B-15	5.3				
B-16	5.1	2.6			1.91
B-17	5.1	2.1	1.0	7.8	2.42
B-18	4.8	2.1	1.0	7.8	2.25
B-19	5.7	1.2			4.71
B-20	4.8	2.7			1.76
B-21	11.4	3.5			3.14
B-22	15.4	5.9			2.62
B-23	26.8	10.4			2.58
B-24	25.3	6.8			3.73
B-25	19.3	6.1			3.18
B-26	24.7	8.2			3.02
B-27	25.3	11.6			2.19
B-28	20.2	9.8			2.06
B-29	11.9	7.0			1.70
B-30	7.8	6.1			1.28
B-31	16.8	4.0			3.87
B-32	18.4	7.1			2.58
B-33	30.6	11.1			2.76
B-34	22.8	7.5			3.03

TABLE 3-B
CITY CAR NO. 244
Analysis of Wheel Revolutions and Time from the Chronograph Records

Run No.	Speed M.P.H.	Total Revolutions at End of Time—Seconds:									
		1	2	3	4	5	6	7	8	9	10
B-2	10.3	2.0	4.0	5.0	6.0						
B-1	16.1	3.0	5.5	8.0	9.5	10.5	11.0				
B-3	18.8	3.5	7.0	10.0	12.5	14.5	16.0	16.5			
B-4	23.7	4.5	8.5	12.5	15.5	18.5	21.0	23.5	25.0	26.5	27.0
B-5	26.8	5.5	10.0	15.0	19.0	22.0	25.5	28.0	30.0	32.0	33.0
B-10	5.7	1.0	1.5								
B-8	21.3	3.5	7.5	10.5	10.3	13.0	14.5	16.0	16.5		
B-18	4.8	1.0									
B-14	5.1	1.0									
B-16	5.1	1.5	2.0								
B-17	5.1	.5	1.0								
B-13	16.7	2.5	5.0	7.0	8.5						
B-12	19.7	3.5	7.0	9.5	12.0	13.5	14.0				

NOTE.—One revolution of the car wheel equals 7.78 ft.

TABLE 4-B

CITY CAR NO. 244

Analysis of the Trainagraph Record

Run No.	Time B.V. to Stop Sec.	Brake Cyl. Max. Press. Lb. Per Sq. In.	Brake Cyl. Min Press. Lb. Per Sq. In.	Brake Cyl. Avg. Press. Lb. Per Sq. In.	Main Reservoir Max. Press. Lb. Per Sq. In.	Main Reservoir Min. Press. Lb. Per Sq. In.	Main Reservoir Avg. Press. Lb. Per Sq. In.	Kind of Braking
B-1	6.6	53.0	50.0	51.5	62.0	52.0	57.0	E.
B-2	5.1	55.0	20.0	37.5	63.0	55.0	59.0	E.
B-3	8.5	51.5	45.0	48.7	60.0	46.0	53.0	E.
B-4	10.6	53.0	44.0	49.0	61.0	44.0	52.5	E.
B-5	11.1	50.0	42.0	46.0	60.0	46.0	53.0	E.
B-6	4.7	60.0	57.0	58.5	73.0	60.0	66.5	E.
B-7	4.9	60.0	57.0	58.5	72.0	60.0	66.0	E.
B-8	7.3	60.0	54.0	57.0	72.0	62.0	67.0	E.
B-9	10.4	59.5	50.0	54.7	69.5	52.0	60.7	E.
B-10	3.0	62.0	62.0	62.0	71.0	64.0	67.5	E.
B-11	9.6	58.0	50.0	54.0	70.0	52.0	61.0	E.
B-12	6.6	60.0	53.0	56.5	70.5	56.0	63.2	E.
B-13	5.3	60.0	55.0	57.5	72.0	59.0	65.5	E.
B-14	4.1	61.5	61.5	61.5	70.0	64.0	67.0	E.
B-15	4.9	60.0	60.0	60.0	70.0	64.0	67.0	E.
B-16		60.0	60.0	60.0	72.0	65.5	68.2	E.
B-18	1.7	62.0	62.0	62.0	71.5	64.5	68.0	E.
B-31		60.0	60.0	60.0	72.0	64.5	68.2	R.M. + E.
B-32	6.8	64.5	64.5	64.5	72.0	66.0	69.0	R.M. + E.
B-33	11.0	60.0	49.0	54.5	70.0	52.0	61.0	R.M. + E.
B-34	7.6	65.0	54.0	58.5	70.0	57.0	63.5	R.M. + E.

TABLE 5-B
CITY CAR NO. 244
Analysis of Time Data from the Trainagraph Record

Run No.	Time B.V. to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Main Reservoir—Sec.	Run No.	Time B.V. to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Main Reservoir—Sec.
B-1	1.55	8.88	B-12	1.72	5.00
B-2	1.22	4.22	B-13	1.78	1.55
B-3	1.39	8.34	B-14	1.94	2.00
B-4	1.78	9.00	B-15	1.94	1.67
B-5	1.55	11.11	B-16	1.94	1.67
B-6	1.78	4.33	B-18	2.00	1.92
B-7	1.58	4.22	B-31	1.78	2.33
B-8	1.62	6.33	B-32	1.67	1.61
B-9	1.78	9.66	B-33	1.78	10.21
B-10	1.89	1.67	B-34	1.67	6.84
B-11	1.78	8.77			

Average Time for Brake Cylinder Pressure to Reach Maximum:
Straight Air Low Pressure_____ 1.48 Sec.
Straight Air High Pressure_____ 1.79 Sec.
Reversed Motors Plus High Pressure Air__ 1.70 Sec.

Average Time for Main Reservoir Pressure to Reach Minimum:
Straight Air Low Pressure_____ 8.31 Sec.
Straight Air High Pressure_____ 5.24 Sec.
Reversed Motors Plus High Pressure Air__ 5.25 Sec.

TABLE 6-B
CITY CAR NO. 244
Analysis of the Speedmeter Record

Run No.	Speed M.P.H.	Stop Time, Seconds	Time from B.V. to Retardation, Seconds	Kind of Braking
B-	11.2	4.4	0.70	E.
B-1	12.5	7.2	1.91	E.
B-2	9.0	5.1	1.54	E.
B-3	15.5	7.7	1.32	E.
B-4	19.2	12.0	1.22	E.
B-5	22.6	11.4	1.17	E.
B-6	10.0	3.9	0.68	E.
B-7	11.2	5.0	1.76	E.
B-8	16.0	----	----	E.
B-9	22.0	10.6	0.64	E.
B-10	4.8	2.8	1.17	E.
B-11	22.5	10.0	0.00	E.
B-12	15.5	7.4	1.94	E.
B-13	12.0	5.5	0.16	E.
B-14	4.0	4.8	0.80	E.
B-15	4.8	----	1.17	E.
B-16	4.0	2.6	0.79	E.
B-17	4.0	2.1	0.95	E.
B-18	4.0	2.0	0.83	E.
B-19	4.5	1.4	0.71	R.M.
B-20	4.0	2.6	0.92	R.M.
B-21	9.0	3.6	0.64	R.M.
B-22	11.5	6.0	0.86	R.M.
B-23	19.5	9.0	1.25	R.M.
B-24	19.5	6.1	1.53	R.M.
B-25	14.5	6.8	1.23	R.M.
B-26	17.6	8.2	0.92	R.M.
B-27	18.5	11.4	0.79	B.M.
B-28	13.6	9.7	0.83	B.M.
B-29	8.5	7.4	0.89	B.M.
B-30	4.8	4.0	0.33	B.M.
B-31	9.0	4.2	0.27	E. + R.M.
B-32	12.0	7.0	0.33	E. + R.M.
B-33	23.0	11.3	0.25	E. + R.M.
B-34	17.5	7.4	0.88	E. + R.M.
B-35	22.4	164.5	----	Coasting

TABLE 7-B

CITY CAR NO. 244

Analysis of the Time from the Stop Indication to the Beginning of Retardation

Run No.	Kind of Braking	Time from B.V. to Retardation. Seconds
	E.	
B-1	Low Air Press.	0.70
B-2	Low Air Press.	1.91
B-3	Low Air Press.	1.54
B-4	Low Air Press.	1.32
B-5	Low Air Press.	1.22
	Average	1.34
	E.	
B-6	High Air Press.	0.68
B-7	High Air Press.	1.76
B-8	High Air Press.	
B-9	High Air Press.	0.64
B-10	High Air Press.	1.17
B-11	High Air Press.	0.00
B-12	High Air Press.	1.94
B-13	High Air Press.	0.16
B-14'	High Air Press.	0.80
B-15	High Air Press.	1.17
B-16	High Air Press.	0.79
B-17	High Air Press.	0.95
B-18	High Air Press.	0.83
	Average	0.91

Run No.	Kind of Braking	Time from B.V. to Retardation, Seconds
B-19	R.M.	0.71
B-20	R.M.	0.92
B-21	R.M.	0.64
B-22	R.M.	0.86
B-23	R.M.	1.25
B-24	R.M.	1.50
B-25	R.M.	1.23
B-26	R.M.	0.92
	Average	1.00
B-27	B.M.	0.79
B-28	B.M.	0.83
B-29	B.M.	0.89
B-30	B.M.	0.33
	Average	0.71
B-31	R.M. + E.	0.27
B-32	R.M. + E.	0.33
B-33	R.M. + E.	0.25
B-34	R.M. + E.	0.88
	Average	0.43

TABLE 8-B

CITY CAR NO. 244

Braking Rates at Different Speeds

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
B-1	14.3	1.34
	11.1	2.80
	7.1	2.87
	2.5	2.76
B-2	10.0	.81
	6.8	3.46
	2.2	2.25
B-4	21.8	1.39
	18.7	1.83
	15.4	2.17
	11.7	2.08
	8.1	2.80
	3.2	2.76

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
B-5	27.0	1.10
	24.5	3.14
	19.0	4.07
	13.6	3.68
	8.4	3.12
	3.1	3.12
B-8	20.3	1.55
	17.5	3.08
	13.4	2.99
	7.5	4.97
	2.0	2.42
B-9	27.4	2.20
	23.5	3.21
	12.4	3.17
	7.4	3.21
	2.6	3.62

TABLE 9-B

BIRNEY CAR NO. 244

Comparison of Stopping Distances as Determined by Several Methods

Run No.	Measured Distance Feet	Distance by Chronograph		Distance by Revolution Counter		Kind of Braking
		Revolution of Car Wheel	Distance Feet	Revolution of Car Wheel	Distance Feet	
B-1	97.8	11.0	85.7	12	93.4	E.
B-2	56.2	6.5	50.6	6	46.7	E.
B-3	152.2			18	140.0	E.
B-4	228.6	28.0	218.0	28	218.0	E.
B-5	275.2	33.5	260.0	34	264.5	E.
B-6	65.6	7.0	54.5	8	62.2	E.
B-7	77.8			9	70.0	E.
B-8	139.3	16.0	124.5	12	93.4	E.
B-9	264.5	31.0	241.5	34	264.5	E.
B-10	14.0	1.5	11.7	2	15.5	E.
B-11	238.7	29.0	225.5	29	225.7	E.
B-12	129.9	14.0	109.0	16	124.3	E.
B-13	88.9	9.5	74.0	11	85.6	E.
B-14	11.5	1.0	7.8	1	7.8	E.
B-15	14.5			3	23.3	E.
B-16	12.5			2	15.5	E.
B-17	12.7	1.0	7.8	1	7.8	E.
B-18	11.4	1.0	7.8	1	7.8	E.
B-31	65.0			3	23.3	R.M.+E.
B-32	120.0			4	31.1	R.M.+E.
B-33	293.0			7	54.4	R.M.+E.
B-34	182.6			6	46.7	R.M.+E.

TABLE 10-B

Comparison of Stopping Time in Seconds as Determined by Several Methods

Run No.	Chrono-graph	Stop Watch	Traina-graph	Speed Meter	Kind of Braking
B-1	6.4	6.4	6.6	7.2	S.
B-2	5.3	4.9	5.1	5.1	S.
B-3	8.7	8.6	8.5	7.7	S.
B-4	10.8	11.4	10.6	12.0	S.
B-5	11.2	11.5	11.1	11.4	S.
B-6	4.7	4.7	4.7	3.9	S.
B-7	4.8	5.2	4.9	5.0	S.
B-8	7.2	7.2	7.3		S.
B-9	10.4	10.5	10.4	10.6	S.
B-10	2.8	2.0	3.0	2.8	S.
B-11	10.0	10.2	9.6	10.0	S.
B-12	6.9	7.1	6.6	7.4	S.
B-13	5.5	5.7	5.3	5.5	S.
B-14	1.9	2.9	4.1	4.8	S.
B-15		2.1	4.9		S.
B-16	2.6	2.9		2.6	S.
B-17	2.1	2.1		2.1	S.
B-18	2.1	2.0	1.7	2.0	S.
B-19	1.2	4.6		1.4	R.M.
B-20	2.7	2.9		2.6	R.M.
B-21	3.5	5.6		3.6	R.M.
B-22	5.9	5.6		6.0	R.M.
B-23	10.4	11.5		9.0	R.M.
B-24	6.8	7.1		6.1	R.M.
B-25	6.1	7.5		6.8	R.M.
B-26	8.2	9.7		8.2	R.M.
B-27	11.6	11.4		11.4	B.M.
B-28	9.8	10.2		9.7	B.M.
B-29	7.0	7.8		7.4	B.M.
B-30	6.1	5.9		4.0	B.M.
B-31	4.0	4.5		4.2	R.M.
B-32	7.1	7.2	6.8	7.0	R.M.
B-33	11.1	10.5	11.0	11.3	R.M.
B-34	7.5	7.8	7.6	7.4	R.M.

TABLE 11-B
CITY CAR NO. 244
Comparison of Stopping Times as Determined from the Trainagraph Record

Run No.	Stop Time B.V. to Stop Seconds	Stop Time from Pressure Curve Seconds	Variation in Pressure at Stop Lb Per Sq. In.
B-1	6.6	6.0	1.5
B-2	5.1	4.5	2.0
B-3	8.5	8.3	0.7
B-4	10.6	10.6	0.5
B-5	11.1	10.9	1.8
B-6	4.7	4.7	1.7
B-7	4.9	4.6	1.7
B-8	7.3	7.0	1.8
B-9	10.4	10.2	1.5
B-10	3.0	2.1	0.5
B-11	9.5	9.4	1.2
B-12	7.6	6.6	1.8
B-13	5.3	5.2	2.0
B-14	4.1	2.0	0.7
B-15	4.9	2.4	1.0
B-16		1.8	0.7
B-18	1.7		
B-19			
B-31		2.3	4.0
B-32	6.8		
B-33	11.0	10.8	3.0
B-34	7.6	7.3	3.0

APPENDIX

SECTION C

TABLE 1-C

TEST LOG CITY CAR NO. 1026

Observers:
Chronograph—C. W. Melephant
Trainagraph—H. Wood, P. B. McGinnis
Speedmeter—M. Aldrich
Motorman—Homer Siegman
Recorder—W. E. Blowers
Time and Revolution Record—M. L. Galey
Gunman—C. H. Clark

Date—May, 18, 1923
Place—Pettigrew Substation
Weather—Cloudy with occasional Sprinkles
Wind—Southwest Breeze

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
C-1	25.10	- - -	22.0 23.2	- - - -	- - -	1200.0	E.	12	East	A.M.	Dry Rail. Speed Test
C-2	22.50	28.0	8.2	66.0	63.0	243.1	E.	12	East	A.M.	Dry Rail Sand Started, 100 feet
C-3	5.75	4.0	2.6 3.4	66.0	63.0	29.0	E.	12	East	A.M.	Dry Rail
C-4	10.50	7.0	4.0 4.5	65.5	62.0	67.8	E.	12	East	A.M.	Dry Rail
C-5	15.50	14.0	6.0 6.1 5.9	65.5	62.0	126.0	E.	12	East	A.M.	Dry Rail
C-6	5.75	3.0	2.8 2.8	66.0	62.5	27.7	E.	12	East	A.M.	Rry Rail
C-7	18.00	9.0	7.3 7.2	66.0	62.5	166.8	E.	12	East	A.M.	Dry Rail
C-8	6.25	4.0	3.6 3.4	56.0	55.0	33.8	E.	12	East	A.M.	Dry Rail
C-9	5.75	4.0	3.4 3.4 3.6	56.0	54.0	32.0	E.	12	East	A.M.	Dry Rail
C-10	9.75	7.0	5.4 4.4	- - -	- - -	66.0	E.	12	East	A.M.	Dry Rail. No Trainagraph Record
C-11	10.50	8.0	5.2 5.0 5.1	56.5	54.0	74.0	E.	12	East	A.M.	Dry Rail
C-12	15.25	18.0	7.0 7.0 7.2	56.5	54.0	144.4	E.	12	East	A.M.	Dry Rail
C-13	19.00	24.0	8.8 8.8	56.5	54.0	205.6	E.	12	East	A.M.	Light Rain

C-14	22.50	31.0	9.8 9.8	56.5	54.0	266.0	E.	12	East	A.M.	Light Rain
C-15	5.00	7.0	6.2 6.6			49.3	R.M.	12	East	A.M.	Dry Rail. Track Sandy from Air Tests (Slow to Start)
C-16	6.50	7.0	7.8 7.8			59.0	R.M.	11	East	A.M.	Dry Rail. Track Sandy from Air Tests
C-17	10.00						R.M.	11	East	A.M.	Dry Rail. Track Sandy. Arc in Overhead. Pulled Trolley
C-18	9.50	17.0	12.6			138.6	R.M.	11	East	A.M.	
C-19							R.M.				Dry Rail. Breaker Blew
C-20	6.00	6.0	5.8 6.4			53.0	B.M.	11	East	A.M.	Dry Rail. Track Sandy. Pulled Trolley instead of Throwing Breaker
C-21	9.50	14.0	9.8 9.8			122.0	B.M.	11	East	A.M.	Dry Rail. Track Sandy. Pulled Trolley instead of Throwing Breaker
C-22								11	East	A.M.	Coasting Record
C-23	15.00	33.0	15.2 15.0			272.8	B.M.	14	East	A.M.	Dry Rail. Pulled Trolley instead of Throwing Breaker. Track Sandy
C-24	5.50	3.0	2.6 2.6	66.0	63.0	26.2	E.	14	East	A.M.	Dry Rail. No Sand
C-25	6.50	4.0	3.0 3.4	66.0	63.0	38.4	R.M.+E.	14	East	A.M.	Dry Rail. Sand
C-26	10.50	8.0	4.6 4.6	66.0	63.0	69.0	R.M.+E.	14	East	A.M.	Dry Rail. Sand. Slid at 43 Feet
C-27	15.50	16.0	6.2 6.4	66.0	63.0	133.5	R.M.+E.	14	East	A.M.	Dry Rail. Sand. Slid at 75 Feet
C-28	19.50	25.0	8.6 8.6	65.5	63.0	218.1	R.M.+E.	14	East	A.M.	Dry Rail. Sand. Breaker Blew, Slid at 69 Feet
C-29	6.50	5.0	3.8 4.0	65.0	63.0	52.4	E.	12	West	P.M.	Dry Rail. Sand
C-30	5.25	4.0	3.4 3.5	65.5	62.5	36.0	E.	12	West	P.M.	Dry Rail. Sand
C-31	12.00	11.5	5.2 5.5 5.6	65.5	62.5	100.0	E.	12	West	P.M.	Dry Rail. Sand Sand
C-32	21.00	411.0	2 Mins. 53.6 Sec.				E.	12	West	P.M.	Dry Rail. Coasting Record
C-33	19.50	23.0	7.6 8.0	66.0	63.5	194.2	E.	12	West	P.M.	Dry Rail. Sand
C-34	5.25	3.0	3.2 3.2	55.5	53.0	33.0	E.	12	West	P.M.	Dry Rail. Sand
C-35	15.50	15.0	6.7 6.6 6.8	56.0	53.5	138.9	E.	12	West	P.M.	Dry Rail. Sand
C-36	19.50	25.0	8.8 8.8 8.4	56.0	54.5	213.5	E.	12	West	P.M.	Dry Rail. Sand

TABLE 1-C (Continued)
TEST LOG CITY CAR NO. 1026

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
C-37	6.00	3.0	2.4 2.6	64.5	61.5	28.5	R.M.+E.	12	West	P.M.	Dry Rail
C-38	14.50	13.0	6.2 6.0	66.0	63.0	118.9	R.M.+E.	12	West	P.M.	Dry Rail. Breaker Blew, Causing Fire. Began Sliding at 36 Feet. from Start
C-39	18.00	20.0	7.6 7.4	65.5	62.5	174.5	R.M.+E.	12	West	P.M.	Dry Rail
C-40	14.50	33.0	16.2 16.0	----	-- -	279.5	R.M.	12	West	P.M.	Dry Rail. Breaker Burning. Trolley Off. B.M. Test. One Point on Controller
C-41	6.00	7.0	7.8 7.2	—	-- -	67.0	R.M.	12	West	P.M.	Dry Rail. Breaker Blew. One Point on Controller
C-42	6.00	6.0	6.2 6.2	-- -	- -	50.0	B.M.	12	West	P.M.	Dry Rail. Trolley Pulled instead of Throwing Breaker
C-43	14.50	30.0	12.3 12.6 12.6	----		191.2	B.M.	12	West	P.M.	Dry Rail. Trolley Pulled instead of Throwing Breaker.
C-44	19.50	58.0	22.2 22.2 22.0	----	-- -	418.5	B.M.	12	West	P.M.	Dry Rail. Trolley Pulled Instead of Throwing Breaker

Standing Piston Travel---- ------- 4 3-16 In.

TABLE 2-C
CITY CAR NO. 1026
Analysis of Chronograph Records

Run No.	Speed M.P.H.	Stop Time Sec	Revolutions B.V. to Stop	Stop Distance Feet	Average Braking Rate M.P.H.P.S.
C-1	35.4	23.5	149.0	1212.0	1.51
C-2	31.5	8.5	27.0	220.0	3.68
C-3	9.9	2.7	3.0	24.4	3.67
C-4	15.2	4.3	8.0 Slip	65.2	3.50
C-5	22.0	6.0	14.0	114.0	3.66
C-6	9.1	3.1	2.0	16.3	2.93
C-7	25.7	7.1	19.0	155.0	3.62
C-8	9.4	3.2	3.5	28.5	2.91
C-9	9.7	4.0	3.0	24.4	2.45
C-10	13.8	4.6	7.0	57.0	3.00
C-11	15.6	5.1	8.0	65.2	3.08
C-12	23.2	7.1	16.5	134.2	3.28
C-13	26.8	8.8	23.5	191.5	3.04
C-14	31.0	9.8	31.0	252.3	3.18
C-15	8.6	6.5	5.5	44.7	1.32
C-16	9.5	9.4	6.5	52.9	1.01
C-17	15.2	----	16.0	130.2	
C-18	14.2	12.9	15.5	126.0	1.09
C-19	22.2	No Stop	27.0	220.0	--
C-20	8.7	6.0	6.0	48.9	1.45
C-21	14.4	9.0	14.0	115.7	1.60
C-22	27.4	85.1	295.0	2405.0	3.37
C-23	21.0	15.1	32.0	262.1	1.40
C-24	9.0	2.8	2.5	20.4	3.21
C-25	11.0	3.6	4.0	32.6	3.07
C-26	15.4	4.4	7.0	57.0	3.59
C-27	22.5	6.5	14.5	108.1	3.46
C-28	28.2	8.5	23.5	191.5	3.30
C-29	12.9	4.1	5.0	42.3	3.14
C-30	10.6	3.1	3.5	28.5	3.38
C-31	19.4	5.9	11.0	89.5	3.29
C-32	29.2	--	412.0	---	----
C-33	26.7	7.7	21.5	175.0	3.46
C-34	8.4	3.0	3.0	24.4	2.82
C-35	23.1	6.9	16.0	130.0	3.36
C-36	28.3	8.7	24.0	195.5	3.24
C-37	8.6	3.7	3.0	24.4	2.30
C-38	22.4	6.2	13.0	105.9	3.64
C-39	27.2	7.2	19.5	159.0	3.72
C-40	21.0	14.6	Slip	---	1.43
C-41	----	7.0	Bad Record	--	--
C-42	8.5	6.0	5.5	44.7	1.42
C-43	20.8	12.5	31.0 Slip	252.2	1.66
C-44	27.8	22.2	58.0 Slip	472.0	1.25

TABLE 3-C

CITY CAR NO. 1026

Analysis of Wheel Revolutions and Time from the Chronograph Records

Run No.	Speed M.P.H	Total Revolutions at End of Seconds:																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
C-6	9.1	1.5	2.5	3.0																			
C-3	9.9	1.5	2.5																				
C-4	15.2	2.5	5.0	6.0	7.0																		
C-5	22.0	4.0	7.5	10.0	12.0	13.5	14.0																
C-7	25.7	4.5	8.5	12.0	14.5	17.0	18.0	18.5															
C-2	31.5	5.5	10.5	15.0	18.5	21.5	24.0	26.0															
C-8	9.4	1.5	2.5	3.0																			
C-9	9.7	1.5	2.5																				
C-10	13.8	2.5	4.5	6.0	6.5																		
C-11	15.6	3.0	5.0	6.5	7.5	8.0																	
C-12	23.2	4.0	7.0	10.5	13.0	14.5	16.0	16.5															
C-13	26.8	4.5	8.5	12.5	15.5	18.5	20.5	22.0	23.0														
C-14	31.0	5.5	10.5	15.0	19.0	22.5	25.5	28.0	29.5	30.5													
C-15	8.6	1.5	3.0	4.0	4.5	5.0																	
C-16	9.5	1.5	3.0	4.0	5.0	5.5	6.0	6.5															
C-18	14.2	2.0	4.5	6.5	8.0	9.5	11.0	12.5	13.5	14.0	15.0												
C-20	8.7	1.5	3.0	4.0	5.0	5.5																	
C-21	14.4	2.5	5.0	7.5	9.5	11.0	12.5	13.5	14.0														
C-23	21.0	4.0	7.5	11.0	14.0	17.0	19.5	22.0	24.0	26.0	29.0	30.0	31.5	32.5	33.0								
C-25	11.0	2.0	3.0	3.5																			
C-26	15.4	2.5	5.0	6.0	6.5																		
C-27	22.5	4.0	7.0	10.0	12.0	13.5	14.0																
C-28	28.2	4.5	9.5	13.0	16.5	19.5	21.5	23.0	23.0														

C-30	10.6	1.5	3.0	3.5																							
C-29	12.9	2.5	4.0	5.0																							
C-31	19.4	3.5	6.5	8.5	10.0	10.5																					
C-33	26.7	4.5	9.0	12.5	16.0	18.5	20.0	21.0																			
C-34	8.5	1.5	2.5	3.0																							
C-35	23.1	4.0	7.5	10.5	12.5	14.5	15.5																				
C-36	28.3	4.5	9.5	13.5	17.0	19.5	22.0	23.5	24.0																		
C-37	8.6	1.5	2.5																								
C-38	22.4	3.5	7.0	9.5	11.5	12.5																					
C-39	27.2	4.5	8.5	12.0	15.5	17.5	19.0	19.5																			
C-42	8.5	1.5	3.0	4.0	5.0	5.5																					
C-43	20.5	4.0	7.5	10.5	14.0	17.5	19.5	22.0	24.5	26.0	27.5	28.5	29.0														
C-44	27.8	5.0	10.5	15.0	19.0	22.5	26.0	29.0	33.0	36.0	39.0	41.5	44.0	46.5	48.0	51.0	52.5	54.0	55.5	56.5	57.5	58.0					

NOTE.—One revolution of the Car Wheel Equals 8.145 Feet.

TABLE 4-C

CITY CAR NO. 1026

Analysis of the Trainagraph Record

Run No.	Time B.V. to Stop Sec.	Brake Cyl. Max. Press. Lb. Per Sq. In.	Brake Cyl. Min Press. Lb. Per Sq. In.	Brake Cyl. Avg. Press. Lb. Per Sq. In.	Main Reservoir Max. Press. Lb. Per Sq. In.	Main Reservoir Min. Press. Lb. Per Sq. In.	Main Reservoir Avg. Press. Lb. Per Sq. In.	Kind of Braking
C-2	8.3	64.0	64.0	64.0	65.0	61.0	63.0	E.
C-3	---	63.0	63.0	63.0	66.0	62.0	64.0	E.
C-4	4.4	62.0	62.0	62.0	65.0	61.0	63.0	E.
C-5	5.8	63.0	63.0	63.0	65.0	61.0	63.0	E.
C-6	2.9	63.0	63.0	63.0	65.0	61.0	63.0	E.
C-7	7.2	63.0	63.0	63.0	65.0	61.0	63.0	E.
C-8	3.1	64.5	64.5	64.5	66.0	63.0	63.0	E.
C-9	---	No Record						
C-10	---	No Record						
C-11	4.5	54.0	54.0	54.0	56.0	52.0	54.0	E.
C-12	7.1	54.0	54.0	54.0	56.0	53.0	54.5	E.
C-13	8.3	54.0	54.0	54.0	55.5	52.5	54.0	E.
C-14	9.5	55.0	55.0	55.0	55.5	52.5	54.0	E.
C-24	2.8	64.0	64.0	64.0	65.5	62.0	63.7	E.
C-25	3.4	64.0	64.0	64.0	65.5	62.0	63.7	R.M. +E.
C-26	4.1	63.5	63.5	63.5	65.5	62.0	63.7	R.M. +E.
C-27	---	64.0	64.0	64.0	65.0	61.0	63.0	R.M. +E.
C-28	7.5	64.0	64.0	64.0	65.0	61.0	63.0	R.M. +E.
C-29	1.1	61.0	61.0	61.0	64.5	60.5	62.5	E.
C-30	3.1	61.5	61.5	61.5	65.0	61.5	63.2	E.
C-31	5.6	61.5	61.5	61.5	65.0	61.0	63.0	E.
C-33	7.6	62.5	62.5	62.5	66.0	62.0	64.0	E.
C-34	2.8	53.0	53.0	53.0	55.0	52.0	53.5	E.
C-35	6.7	53.0	53.0	53.0	55.0	52.0	53.5	E.
C-36	8.6	53.0	53.0	53.0	55.0	52.0	53.5	E.
C-37	3.7	66.	60.0	60.0	64.5	60.0	62.2	R.M. +E.
C-38	6.0	61.0	61.0	61.0	65.0	60.5	62.7	R.M. +E.
C-39	6.9	62.0	62.0	62.0	65.0	61.0	63.0	R.M. +E.

TABLE 5-C
CITY CAR NO. 1026
Analysis of the Time Data from the Trainagraph Record

Run No.	Time B.V. to to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Emergency Pipe, Sec.	Run No.	Time BV. to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Main Reservoir, Sec.
C-1	Coasting	Test	C-26	1.11	1.11
C-2	1.11	1.11	C-27	1.11	1.11
C-3	1.00	1.00	C-28	1.11	1.00
C-4	.89	1.11	C-29	1.00	1.00
C-5	1.00	1.11	C-30	1.00	1.00
C-6	1.06	1.11	C-31	1.00	.89
C-7	1.00	1.06	C-32	1.00	1.00
C-8	1.11	.78	C-33	1.00	1.00
C-11	1.00	.89	C-34	1.00	1.00
C-12	1.00	.89	C-35	1.00	1.00
C-13	1.00	1.00	C-36	1.11	.95
C-14	1.00	.89	C-37	.89	.84
C-24	1.11	1.11	C-38	1.00	.89
C-25	1.00	1.00	C-39	1.11	1.00

Average Time for Brake Cylinder Pressure to Reach Maximum:
Emergency Air---------- 1.02 Sec.
R.M.+E.---------- 1.05 Sec.
Average Time forMain Reservoir Pressure to Reach Minimum:
Emergency Air---------- .98 Sec.
R.M.+E.---------- .99 Sec.

TABLE 6-C
CITY CAR NO. 1026
Analysis of the Speedmeter Record

Run No.	Speed M.P.H.	Stop Time, Seconds	Time from B.V. to Retardation, Seconds	Kind of Braking
C-1	25.50	23.1	----	Speed Test
C-2	22.30	8.8	1.16	E.
C-3	5.75	3.1	1.42	E.
C-4	10.40	4.3	1.66	E.
C-5	15.50	6.1	1.50	E.
C-6	5.75	3.3	1.75	E.
C-7	18.00	7.2	1.42	E.
C-8	6.30	3.5	1.66	E.
C-9	5.75	3.1	1.72	E.
C-10	9.80	4.7	1.31	E.
C-11	10.40	5.1	1.74	E.
C-12	15.30	7.0	1.44	E.
C-13	19.00	9.5	1.45	E.
C-14	22.50	9.6	1.30	E.
C-15	5.00	6.8	1.75	R.M
C-16	6.40	7.1	1.38	R.M.
C-17	10.00	----	----	R.M.
C-18	9.60	13.3	1.25	R.M.
C-19	15.25	10.6	1.12	R.M.
C-20	6.00	6.4	2.82	B.M.
C-21	9.75	8.5	1.60	B.M.
C-22	19.50	8.3	-----	Coasting Test
C-23	14.80	14.8	1.39	B.M.
C-24	5.40	3.0	1.33	R.M.+E.
C-25	6.75	3.6	1.33	R.M.+E.
C-26	10.30	4.8	1.33	R.M.+E.
C-27	15.00	6.3	1.33	R.M.+E.
C-28	19.6	7.9	1.16	----
C-29	6.50	4.0	1.75	R.M.+E.
C-30	5.30	3.3	1.72	R.M.+E.
C-31	12.10	5.8	1.08	R.M.+E.
C-32	21.00	174.5	1.07	Coasting Test
C-33	19.50	7.4	---	E.
C-34	5.30	3.3	1.74	E.
C-35	15.50	7.5	1.67	E.
C-36	19.70	8.6	1.17	E.
C-37	6.00	3.6	1.67	R.M.+E.
C-38	14.75	5.8	1.33	R.M.+E.
C-39	18.00	6.9	---	R.M.+E.
C-40	14.75	13.7	0.77	R.M.
C-41	6.00	5.4	2.67	R.M.
C-42	6.00	5.9	1.75	B.M.
C-43	14.60	13.0	1.75	B.M.
C-44	19.50	22.0	1.75	B.M.

TABLE 7-C
CITY CAR NO. 1026
Analysis of the Time from the Stop Indication to the Beginning of Retardation

Run No.	Kind of Braking	Time from B.V. to Retardation, Seconds
	E.	
C-2	High Press. Air	1.16
C-3	High Press. Air	1.42
C-4	High Press. Air	1.66
C-5	High Press. Air	1.50
C-6	High Press. Air	1.70
C-7	High Press. Air	1.42
C-28	High Press. Air	1.16
C-29	High Press. Air	1.75
C-30	High Press. Air	1.72
C-31	High Press. Air	1.08
C-32	High Press. Air	1.07
C-33	High Press. Air	----
	Average	1.48
	E.	
C-8	Low Press. Air	1.66
C-9	Low Press. Air	1.72
C-10	Low Press. Air	1.31
C-11	Low Press. Air	1.74
C-12	Low Press. Air	1.44
C-13	Low Press. Air	1.45
C-14	Low Press. Air	1.30
C-34	Low Press. Air	1.74
C-35	Low Press. Air	1.67
C-36	Low Press. Air	1.17
	Average	1.52

Run No.	Kind of Braking	Time from B.V. to Retardation, Seconds
C-15	R.M.	1.75
C-16	R.M.	1.28
C-18	R.M.	1.25
C-40	R.M.	0.77
C-41	R.M.	2.67
	Average	1.54
C-20	B.M.	2.82
C-21	B.M.	1.60
C-23	B.M.	1.39
C-42	B.M.	1.75
C-43	B.M.	1.75
C-44	B.M.	1.75
	Average	1.83
C-37	R.M. + E.	1.67
C-38	R.M. + E.	1.33
C-39	R.M. + E.	----
C-24	R.M. + E.	1.33
C-25	R.M. + E.	1.33
C-26	R.M. + E.	1.33
C-27	R.M. + E.	1.33
	Average	1.39

TABLE 8-C
CITY CAR NO. 1026
Braking Rates at Different Speeds

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
C-4	14.7	3.93
	14.3	4.72
	10.1	3.42
	8.0	5.08
C-5	21.6	1.33
	19.2	3.81
	13.9	3.69
C-7	25.0	1.06
	22.3	3.22
	18.3	2.74
	13.3	4.79
C-10	15.6	1.44
	12.8	3.00
	10.0	3.99
C-12	21.2	2.80
	17.6	3.09
	12.7	4.19
C-13	25.5	1.14
	24.8	1.99
	21.7	3.63
	18.4	3.60
	14.5	3.54

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
C-14	31.8	1.34
	29.5	2.93
	27.9	4.06
	22.4	3.86
	21.9	3.18
	12.9	3.78
C-33	27.5	.89
	24.8	2.18
	22.6	4.53
	19.0	3.00
	13.9	4.50
C-35	21.2	1.06
	17.7	3.59
	12.9	3.82
C-36	28.2	.87
	24.8	3.86
	21.2	2.72
	17.5	3.42
	12.9	3.72
C-38	21.3	.39
	18.6	3.20
	13.6	4.64

TABLE 9-C
CITY CAR NO. 1026
Comparisons of Stopping Distances as Determined by Several Methods

Run No.	Measured Distance, Feet	Distance by Chronograph		Distance by Revolution Counter		Kind of Braking
		Revolution of Car Wheel	Distance Feet	Revolution of Car Wheel	Distance Feet	
C-2	243.1	27.0	220.0	28.0	228.0	E.—High Press.
C-3	29.0	3.0	24.4	4.0	32.6	E.—High Press.
C-4	67.8	8.0	65.2	7.0	57.0	E.—High Press.
C-5	126.0	14.0	114.0	14.0	114.0	E.—High Press.
C-6	27.7	2.0	16.3	3.0	24.4	E.—High Press.
C-7	166.8	19.0	155.0	19.0	155.0	E.—High Press.
C-24	26.2	2.5	20.4	3.0	24.4	E.—High Press.
C-29	52.4	5.0	42.3	5.0	40.7	E.—High Press.
C-30	36.0	3.5	28.5	4.0	32.6	E.—High Press.
C-31	100.0	11.0	89.5	12.0	----	E.—High Press.
C-33	194.2	21.5	175.0	19.5	228.0	E.—High Press.
C-8	33.8	3.5	28.5	4.0	32.6	E.—Low Press.
C-9	32.0	3.0	24.4	4.0	32.6	E.—Low Press.
C-10	66.0	7.0	57.0	7.0	57.0	E.—Low Press.
C-11	74.0	8.0	65.2	8.0	65.0	E.—Low Press.
C-12	144.4	16.5	134.2	17.0	138.5	E.—Low Press.
C-13	205.6	23.5	191.5	24.0	195.5	E.—Low Press.
C-14	266.0	31.0	252.3	31.0	252.0	E.—Low Press.
C-34	33.0	3.0	24.4	3.0	24.4	E.—Low Press.
C-35	138.9	16.0	130.0	15.0	122.0	E.—Low Press.
C-36	213.5	24.0	195.5	25.0	204.0	E.—Low Press.
C-15	49.3	5.5	44.7	7.0	57.0	R.M.
C-16	59.0	6.5	52.9	7.0	57.0	R.M.
C-18	138.6	15.5	126.0	17.0	138.5	R.M.
C-40	279.5	----	----	33.0	269.0	R.M.
C-41	67.0	----	----	7.0	57.0	R.M.
C-20	53.0	6.0	48.9	6.0	48.8	B.M.
C-21	122.0	14.0	115.7	14.0	113.0	B.M.
C-23	272.8	32.0	262.1	33.0	269.0	B.M.
C-42	50.0	5.5	44.7	6.0	48.8	B.M.
C-43	191.2	31.0	252.2	30.0	244.0	B.M.
C-44	418.5	58.0	472.0	58.0	471.0	B.M.
C-25	38.4	4.0	32.6	4.0	32.6	E.+R.M.
C-26	69.0	7.0	57.0	8.0	65.2	E.+R.M.
C-27	133.5	14.5	108.1	16.0	130.0	E.+R.M.
C-28	218.1	23.5	191.5	25.0	204.0	E.+R.M.
C-37	28.5	3.0	24.4	13.0	24.4	E.+R.M.
C-38	118.9	13.0	105.9	13.0	106.0	E.+R.M.
C-39	174.5	19.5	159.0	20.0	163.0	E.+R.M.

TABLE 10-C
CITY CAR NO. 1026
Comparison of Stopping Time in Seconds as Determined by Several Methods

Run No.	Chrono-graph	Stop Watch	Traina-graph	Speed Meter	Kind of Braking
					E
C-2	8.6	8.2	8.3	8.8	High Press.
C-3	2.7	3.0		3.1	High Press.
C-4	4.3	4.3	4.4	4.3	High Press.
C-5	6.0	6.0	5.8	6.1	High Press.
C-6	3.1	2.8	2.9	3.3	High Press.
C-7	7.1	7.2	7.2	7.2	High Press.
C-24	2.8	2.6	2.8	3.0	High Press.
C-29	4.1	3.9	1.1	4.0	High Press.
C-30	3.1	3.4	3.1	3.3	High Press.
C-31	5.9	5.4	5.6	5.8	High Press.
C-33	7.7	7.8	7.6	7.4	High Press.
					E
C-8	3.2	3.5	3.1	3.5	Low Press.
C-9	4.0	3.4		3.1	Low Press.
C-10	4.6	4.9		4.7	Low Press.
C-11	5.1	5.1	4.5	5.1	Low Press.
C-12	7.1	7.1	7.1	7.0	Low Press.
C-13	8.8	8.8	8.3	9.5	Low Press.
C-14	9.8	9.8	9.5	9.6	Low Press.
C-34	3.0	3.2	2.8	3.3	Low Press.
C-35	6.9	6.7	6.7	7.5	Low Press.
C-36	8.7	8.7	8.6	8.6	Low Press.
C-15	6.5	6.4		6.8	R. M.
C-16	9.4	7.8		7.1	R. M.
C-17					R. M.
C-18	12.9	12.6		13.3	R. M.
C-40	14.6	16.1		13.7	R. M.
C-41	7.0	7.5		5.4	R. M.
C-20	6.0	6.1		6.4	B.M.
C-21	9.0	9.8		8.5	B.M.
C-23	15.1	15.1		14.8	B.M.
C-42	6.0	6.2		5.9	B.M.
C-43	12.5	12.5		13.0	B.M.
C-44	22.2	22.2		22.0	B.M.
C-25	3.6	3.2	3.4	3.6	R.M. + E.
C-26	4.4	4.6	4.1	4.8	R.M. + E.
C-27	6.5	6.3		6.3	R.M. + E.
C-28	8.5	8.6	7.5	7.9	R.M. + E.
C-37	3.7	2.5	3.7	3.6	R.M. + E.
C-38	6.2	6.1	6.0	5.8	R.M. + E.
C-39	7.2	7.5	6.9	6.9	R.M. + E.

APPENDIX

SECTION D

TABLE 1-D

TEST LOG BIRNEY CAR NO. 55

Observers:
Chronograph—C. W. Melephant
Trainagraph—H. Woods, P. B. McGinnis
Speedmeter—M. Aldrich
Motorman—C. E. Masterson
Recorder—W. E. Blowers
Gunman—C. H. Clark
Time and Revolution Record—W. L. Galey

Date—May 17, 1923
Place—Pettigrew Substation
Weather—Bright Sun
Wind—West

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Piston Travel at End of Run Inches	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
D-1	26.00	154.0	21.4 21.8	----	----	1000.0	-----	----	18	East	A.M.	Speed Run. 1900 Lbs. Dead Weight
D-2	20.00	318.0	----	----	----	----	-----	----	18	East	A.M.	Coasting. 1900 Lbs. Dead Weight
D-3	22.50	-----	---	----	----	----	----	---	18	East	A.M.	Coasting. 1900 Lbs. Dead Weight
D-4	22.00	-----	----	---	----	----	----	-----	18	East	AM.	Coasting. 1900 Lbs Dead Weight
D-5	6.50	5.0	3.0 3.2	72.0	69.0	30.0	----	E.	18	East	A.M.	Coasting 1900 Lbs Dead Weight
D-6	6.00	4.0	2.8	69.0	65.0	25.6	7.25	Hand [illegible]p	18	East	A.M.	
D-7	-----	-----	----	----	----	----		Hands Up	18	East	A.M.	Breaker Stuck. 1900 Lbs. Dead Weight
D-8	-----	-----	----	----	----	----	----	Hands Up	18	West	A.M.	Breaker Stuck. 1900 Lbs. Dead Weight
D-9	6.00	3.5	2.4 2.6	73.5	68.0	21.0	7.75	Hands Up	18	West	A.M.	1900 Lbs. Dead Weight
D-10	11.0	8.0	3.8 3.3 3.3	72.0	67.5	53.7	7.75	Hands Up	18	West	A.M.	1900 Lbs.Dead Weight
D-11	-----	3.0	---	---	----	----	---	Hands Up	18	West	A.M.	No Record. 1900 Lbs. Dead Weight
D-12	6.00	3.0	2.2 2.2 2.1	73.5	69.0	20.6	----	Hands Up	18	West	A.M.	1900 Lbs. Dead Weight
D-13	6.50	3.5	2.2 2.2	68.5	64.0	23.0	---	Hands Up	18	West	A.M.	1900 Lbs. Dead Weight
D-14	9.75	5.0	3.0 2.8	72.0	67.0	37.0	----	Hands Up	18	West	A.M.	1900 Lbs. Dead Weight
D-15	11.50	8.0	3.6 3.5 3.6	71.0	66.0	56.0	-----	Hands Up	18	West	A.M.	1900 Lbs. Dead Weight
D-16	12.50	9.0	3.8 3.8 3.8	68.0	62.0	63.7	----	E.	18	West	P.M.	No Chronograph Record. 1900 Lbs. Dead Weight

D-17	6.50	3.5	2.6 2.1 2.8	71.0	65.0	33.0	.	E.	18	West	P.M.	1900 Lbs. Dead Weight
D-18	6.0	4.0	2.6 2.8	69.0	63.0	25.0		E.	18	West	P.M.	1900 Lbs. Dead Weight
D-19	11.50	8.0	3.6 3.6	72.0	66.0	54.6	. . .	E.	18	West	P.M.	1900 Lbs. Dead Weight
D-20	14.50	12.0	4.6 4.4 4.5	72.0	66.0	76.5	.	E.	18	West	P.M.	1900 Lbs. Dead Weight
D-21	19.50	19.0	5.4 6.0 6.0	69.0	62.0	125.4	.	E.	18	West	P.M.	1900 Lbs. Dead Weight
D-22	20.50	20.0	6.0 6.0 6.0	72.0	65.0	134.1		E.	18	West	P.M.	1900 Lbs. Dead Weight
D-23	7.50	4.0	2.6 2.4 2.6	71.0	65.0	29.5		E.	18	West	P.M.	1900 Lbs. Dead Weight
D-24	20.70	21.0	6.0 6.0 6.0	68.5	64.0	134.9	.	Hands Up	18	West	P.M.	1900 Lbs. Dead Weight
D-25	7.00	6.0	2.4	69.0	64.0	27.8		Hands Up	17	West	P.M.	
D-26	5.25	2.0	1.8 1.8	73.0	67.5	17.5		Hands Up	17	West	P.M.	High Pressure. 1900 Lbs. Dead Weight
D-27	11.25	8.0	3.6 3.6	74.0	68.5	56.2	. .	Hands Up	17	West	P.M.	High Pressure. 1900 Lbs. Dead Weight
D-28	12.40	9.0	4.0 4.0	73.0	67.0	63.5	.	Hands Up	17	West	P.M.	High Pressure. 1900 Lbs. Dead Weight
D-29	14.70	12.0	4.4 4.4 4.4	71.0	66.0	81.1	. .	Hands Up	17	West	P.M.	Hands Pressure. 1900 Lbs. Dead Weight
D-30	17.00	14.0	5.0 5.0 5.2	71.5	67.0	98.2	. . .	Hands Up	17	West	P.M.	High Pressure. 1900 Lbs. Dead Weight
D-31	5.75	2.0	2.2 2.4 2.6	62.0	58.0	20.9	.	Hands Up	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight
D-32	11.50	8.0	3.8 4.2	62.5	58.5	59.0	. .	Hands Up	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight
D-33	15.25	13.0	4.8 4.8 5.0	62.0	58.5	94.2	. . .	Hands Up	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight
D-34	19.40	21.0	6.4 6.6 6.0	61.0	56.5	137.3	. .	Hands Up	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight

TABLE 1-D (Continued)
TEST LOG BIRNEY CAR NO. 55

Run No.	Approx. Speed M.P.H.	Wheel Rev. (Counter)	Stop Time Seconds	Brake Pipe Pressure Lb. Per Sq. In.	Brake Cyl. Pressure Lb. Per Sq. In.	Measured Stop Distance Feet	Piston Travel at End of Run Inches	Kind of Braking	Load (People)	Direction of Run	Time of Day	Remarks
D-35	20.00	22.0	6.4 6.6 6.6	61.5	57.0	149.5	. .	Hands Up	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight
D-36	7.40	6.0	3.4 3.0 3.4	61.5	56.5	41.0	..	E.	17	West	P.M.	Low Pressure. 1900 Lbs. Dead Weight
D-37	10.75	9.0	4.2 4.4 4.0	61.0	56.5	65.0	...	E.	17	West	PM	Low Pressure. 1900 Lbs. Dead Weight
D-38	11.00	10.0	4.2 4.4 4.2	61.0	56.5	68.5	.....	E.	17	West	P.M	No Chronograph Chart. 1900 Lbs Dead Weight
D-39	21.00	25.0	7.6 7.8 7.4	60.5	56.0	175.3	.. ..	E.	17	West	P.M.	Started Sand One Car Length. 1900 Lbs. Dead Weight
D-40	15.25	14.5	5.4 5.2	61.0	56.5	98.6	.. ..	E.	17	West	P.M.	1900 Lbs. Dead Weight
D-41	6.00	4.0	3.4 3.4	.. .	....	26.0		R.M.	19	West	PM.	RM. With One Point—Without Sand 1900 Lbs Dead Weight
D-42	11.00	17.0	6.0	....	....	106.3	. ..	R.M.	18	West	P.M.	R.M. With One Point (Motors off before Complete Stop). 1900 Lbs. Dead Weight
D-43	11.00	13.0	8.0 7.2 7.8	.. .	.. .	85.6	. .	R.M.	18	West	P M.	R.M With One Point. 1900 Lbs. Dead Weight
D-44	15.00	30.0	10.4 10.0 10.4	....	....	167.5	...	R.M.	18	West	P.M.	R.M. With One Point. End of 45 Ft. Wheels Start Backwards. 1900 Lbs. Dead Weight
D-45	6.25	8.0	6.4 5.5 5.5	....	. .	56.4	. ..	B.M.	18	West	P.M.	R.M. With One Point. Car Slid 12 Ft. 1900 Lbs. Dead Weight
D-46	11.00	14.0	9.0 9.2 9.2	....	....	122.0	. ..	B.M.	18	West	P.M.	R.M. With One Point. Car Slid 54 Ft. 1900 Lbs. Dead Weight
D-47	15.25	29.0	13.8 13.9 13.8	....	.. .	206.6	....	B.M.	18	West	P.M.	R.M. With One Point. Car Slid 122 Ft. 1900 Lbs. Dead Weight
D-48	25.00	40.0	9.4 9.4 9.4	67.0	61.0	261.8	.. ..	E.	14	East	P.M.	Sand 60 Ft. After Start. 2000 Lbs. Dead Weight

D-49	6 59	4 0	2.8 2.8 3.0	71.5	65.0	28.5		E.	14	East	P.M.	2000 Lb. Dead Weight
D-50	11 40	8 0	4.0 4.0 4.0	70.5	64.5	61.0	-	E.	14	East	P.M.	No Chronograph. 2000 Lb. Dead Weight
D-51	16.00	15 0	5.4 5.6	71.0	64.5	105.6		E.	14	East	P.M	2000 Lb. Dead Weight
D-52	5.50	3 5	2.0 2.2 2.0	72.0	67.0	21.0		Hands Up	14	East	P.M.	2000 Lb Dead Weght
D-53	11 50	9 0	3.6 3.6 3.6	70.5	66.5	57.6		Hands Up	14	East	P.M.	2000 Lb. Dead Weight
D-54	15 00	14 0	5.0 5.0 5.0	70.0	65 0	92.8		Hands Up	14	East	P.M.	2000 Lb. Dead Weight
D-55	14.50	13 0	4.6 4.8 4.8	72.0	67 0	84.0	-	Hands Up	14	East	P.M.	2000 Lb. Dead Weight
D-56	19 50	20 0	6.2 6.0 6.5	69.5	65.0	137.8	- -	Hands Up	14	East	P.M.	2000 Lb. Dead Weight
D-57	21 75	23 0	6.2 6.5 6.2	70.0	65.0	157.3	- -	Hands Up	14	East	P.M.	2000 Lb. Dead Weight
D-58	7.00	4 0	2.4 2.4 2.4	71.0	66.5	28 0	-	Hands Up	14	East	P.M.	
D-59	5 75	3 0	2.2 2.2	72.0	68.0	21.0		Hands Up	9	East	P.M.	
D-60	11 00	7 0	3.4 3.4 3.2	71.0	67.0	51.8	-	Hands Up	9	East	P.M.	
D-61	15 00	13 5	4.8 4.8	70.5	66.0	89 4	- - -	Hands Up	9	East	P.M.	
D-62	23 00	25.0	6.4 6.4	68.5	64.0	169.6	-	Hands Up	9	East	P.M.	
D-63	10 25	6.0	3.4 3.4 3.5	61.0	57.5	50.6		Hands Up	9	East	P.M.	Low Pressure
D-64	5 75	3.0	2 4 2 4	62.0	59.0	21 5		Hands Up	9	East	P.M.	Low Pressure
D-65	16 00	14 0	4.8 4.8	61.5	57.0	100.1		Hands Up	9	East	P.M.	Low Pressure
D-66	23 00	25 0	6.6 6.6	60.0	56.0	167.6	-	Hands Up	9	East	P.M.	Low Pressure
D-67	----		-- -	----	----	----	7.5	-	14	East	P.M.	Acceleration on Chronagraph.

NOTE.—Brake Cylinder Leakage Test—Car Standing 75 Lb. to 56 Lb., 2 Min. 23 Sec.

TABLE 2-D
BIRNEY CAR NO. 55
Analysis of Chronograph Records

Run No.	Speed M.P.H.	Stop Time Sec.	Revolutions B.V. to Stop	Stop Distance Feet	Average Braking Rate M.P.H.P.S.
D-1	28.9	21.9	153.0	----	----
D-2	25.9	128.3	314.0	----	----
D-3	27.6	----	415.0	----	----
D-4	27.6	133.7	----	----	----
D-5	----	----	----	----	----
D-6	----	----	----	----	----
D-7	8.3	2.5	----	----	----
D-8	8.3	2.8	----	----	----
D-9	8.1	2.5	----	----	3.19
D-10	13.8	3.7	----	----	3.73
D-11	----	----	----	----	----
D-12	8.3	3.8	----	----	2.18
D-13	8.9	2.4	3.0	19.3	3.78
D-14	12.1	2.9	----	----	4.17
D-15	14.5	3.3	----	----	4.93
D-16	----	----	----	----	----
D-17	8.5	2.3	2.0	12.9	3.70
D-18	8.5	2.2	2.0	12.9	3.86
D-19	14.5	3.8	7.0	45.1	4.10
D-20	18.3	4.0	9.0	58.0	4.54
D-21	23.4	5.4	16.5	106.3	3.57
D-22	24.4	5.6	17.0	109.6	4.23
D-23	10.1	2.5	3.5	22.6	4.18
D-24	25.5	5.9	18.0	116.0	4.29
D-25	9.6	2.6	3.0	19.3	3.64
D-26	7.5	2.0	1.5	9.7	3.79
D-27	15.7	3.5	7.0	46.4	4.41
D-28	16.7	3.7	8.0	51.6	4.38
D-29	18.4	4.6	11.0	70.9	4.02
D-30	20.9	4.9	13.0	83.8	4.22
D-31	7.7	2.3	2.0	12.9	3.56
D-32	14.5	3.7	7.5	48.4	4.06
D-33	20.3	4.9	12.5	81.0	4.17
D-34	23.5	6.3	19.0	122.4	4.05
D-35	24.6	6.4	20.0	129.0	3.71
D-36	10.7	2.7	3.5	23.9	4.12
D-37	----	----	----	----	----
D-38	15.6	4.2	8.5	55.0	3.45
D-39	27.1	7.2	23.0	148.0	3.50
D-40	19.4	5.3	13.0	83.0	3.67
D-41	7.5	3.0	3.0	19.3	2.64
D-42	14.2	13.7	17.0	109.5	1.11
D-43	14.6	8.1	13.0	83.8	1.87
D-44	19.3	10.5	30.0	193.5	1.88
D-45	8.2	6.1	7.0	45.1	1.40
D-46	14.7	8.7	12.0	77.3	2.26
D-47	19.4	12.2	27.0	174.0	1.67
D-48	28.8	8.6	33.0	212.7	3.31
D-49	8.8	2.6	3.0	19.3	3.59
D-50	----	----	----	----	----
D-51	20.2	5.3	14.0	90.1	3.77
D-52	8.0	2.3	3.0	19.3	3.48
D-53	14.5	3.9	7.5	48.3	3.94
D-54	----	----	----	----	----
D-55	19.2	4.8	11.5	74.1	3.99
D-56	24.2	5.9	18.5	119.0	4.22
D-57	26.8	6.4	22.0	142.0	4.17
D-58	10.0	2.4	3.0	19.3	4.21
D-59	8.4	2.2	2.5	16.1	4.05
D-60	14.4	3.4	7.0	45.0	4.24
D-61	20.3	4.7	12.0	77.3	4.29
D-62	27.0	6.6	23.5	152.0	4.37
D-63	13.4	3.5	6.5	42.0	3.83
D-64	8.4	2.1	2.0	12.9	3.98
D-65	20.2	5.2	13.0	83.8	4.02
D-66	27.5	6.6	24.0	155.0	4.20

TABLE 3-D
BIRNEY CAR NO. 55
Analysis of Wheel Revolutions and Time from the Chronograph Records

Run No.	Speed M.P.H.	Total Revolutions at End of Seconds:										
		1	2	3	4	5	6	7	8	9	10	11
D-52	8.0	1.5										
D-53	14.5	3.0	6.0	7.5								
D-55	19.2	4.0	8.0	10.0	11.5							
D-56	24.2	5.5	10.0	14.0	17.0	18.5						
D-57	26.8	6.0	11.0	15.5	19.0	21.0						
D-26	7.5	1.5										
D-25	9.6	2.0	3.0									
D-27	15.7	3.5	6.0									
D-28	16.7	3.5	6.5	8.0								
D-29	18.4	4.0	7.5	10.0								
D-30	20.9	4.5	8.5	11.5	13.5							
D-24	25.5	5.5	10.5	14.0	16.5							
D-31	7.7	1.5										
D-32	14.5	3.5	6.0	7.5								
D-33	20.3	4.5	8.5	11.0	13.0							
D-34	23.5	5.5	10.0	13.5	19.0							
D-35	24.6	5.5	10.5	14.5	17.5	19.5						
D-41	7.5	1.5	3.0									
D-42	14.2	3.5	6.5	9.0	12.0	15.0	16.5					
D-43	14.6	3.5	6.0	8.0	11.0	13.0						
D-44	19.3	4.0	8.0	11.0	15.5	19.5	23.0	25.5	28.0			
D-45	8.2	2.0	4.0	6.0								
D-46	14.7	3.5	7.0	9.5	11.0	12.5	13.0	13.5				
D-47	19.4	4.5	9.0	11.0	14.0	17.0	20.0	22.5	25.0	26.5	27.0	27.5
D-49	8.8	2.0	3.0									
D-51	20,2	4.5	8.0	11.5	13.5							
D-48	28.8	6.0	12.5	18.0	23.0	26.5	29.5	32.0	33.5			
D-17	8.5	1.5										
D-18	8.5	1.5										
D-23	10.1	2.0	3.5									
D-19	14.5	3.5	6.0	8.0								
D-20	18.3	4.0	7.0	9.0								
D-21	23.4	5.0	9.5	13.0	15.5	16.5						
D-22	24.4	5.5	9.5	13.5	16.0	17.0						
D-36	10.7	2.0	3.5									
D-38	15.6	3.5	6.5	9.0								
D-40	19.4	4.0	8.0	10.5	12.5	13.0						
D-39	27.1	6.0	11.0	15.0	18.5	21.5	23.0					
D-58	10.0	2.0										
D-59	8.4	2.0										
D-60	14.4	3.5	6.0	7.0								
D-61	20.3	4.0	8.5	11.0								
D-62	27.0	6.0	11.5	16.5	19.5	22.5	23.5					
D-64	8.4	2.0	3.0									
D-63	13.4	3.0	5.5	6.5								
D-65	20.2	4.5	8.0	11.0								
D-66	27.5	6.5	12.0	16.5	20.0	22.5	23.5					

TABLE 4-D
BIRNEY CAR NO. 55
Analysis of the Trainagraph Record

Run No.	Time B.V. to Stop Sec.	Brake Cyl. Max. Press. Lb. Per Sq. In.	Brake Cyl Min. Press. Lb. Per Sq. In.	Brake Cyl. Ave. Press. Lb. Per Sq. In.	Emergency Pipe Pressure Lb. Per Sq. In.	Main Reservoir Pressure at Start Lb. Per Sq. In.	Main Reservoir Pressure at Stop Lb. Per Sq. In.	Main Reservoir Pressure Average Lb. Per Sq. In.	Kind of Braking
D-1	Speed Run								
D-2	Coasting Run								
D-3	Coasting Run								
D-4	Coasting Run								
D-5	No Record								
D-6	3.1	66.0	65.0	65.5	70.0	65.0	63.0	64.0	Hands Up
D-7	No Record								Hands Up
D-8	No Record								Hands Up
D-9	No Record								Hands Up
D-10	No Record								Hands Up
D-11	No Record								Hands Up
D-12	2.2	70.0	70.0	70.0	75.0	75.0	67.0	71.0	Hands Up
D-13	2.5	64.5	64.5	64.5	70.0	69.0	63.0	66.0	Hands Up
D-14	3.0	68.0	67.0	67.5	73.0	74.0	67.0	70.5	Hands Up
D-15	3.6	67.0	66.0	66.5	72.0	72.0	65.0	78.5	Hands Up
D-16	3.7	63.0	62.0	62.5	70.0	68.0	60.0	64.0	E.
D-17	No Record								E.
D-18	2.1	65.0	65.0	65.0	70.0	68.0	61.0	64.5	E.
D-19	3.7	66.5	65.5	66.0	72.0	71.0	73.0	72.0	E.
D-20	3.8	66.5	65.5	66.0	72.0	71.0	73.0	72.0	E.
D-21	5.5	65.0	64.0	64.5	70.0	68.0	60.0	64.0	E.
D-22	5.6	66.0	64.5	65.2	70.0	69.0	60.0	64.5	E.
D-23	2.7	66.0	66.0	66.0	70.0	69.5	62.0	65.7	E.
D-24	6.2	66.0	64.0	65.0	69.0	66.0	59.0	62.5	Hands Up
D-25	1.9	65.0	65.0	65.0	70.0	68.0	62.5	65.2	Hands Up
D-26	2.2	69.0	69.0	69.0	72.5	72.0	66.0	69.0	Hands Up
D-27	3.5	70.0	68.0	69.0	75.0	72.5	65.0	69.3	Hands Up
D-28	3.7	69.0	67.0	68.0	72.0	71.5	64.0	68.7	Hands Up
D-29	4.5	66.5	65.0	65.7	70.0	69.5	61.0	65.2	Hands Up
D-30	5.0	68.0	65.0	66.5	70.0	70.0	63.0	66.5	Hands Up

D-31	2.4	60.0	60.0	60.0	60.0	61.0	60.0	55.5	57.7	Hands Up
D-32	3.9	60.0	60.0	60.0	60.0	61.0	60.0	55.5	57.7	Hands Up
D-33	4.8	59.0	57.0	58.0	58.0	60.0	59.0	54.5	57.2	Hands Up
D-34	6.1	57.0	55.0	56.0	56.5	60.0	57.0	52.0	55.5	Hands Up
D-35	6.1	60.0	57.0	58.0	58.5	60.0	60.0	53.0	56.5	E.
D-36	3.0	58.0	58.0	58.0	58.5	60.0	57.0	50.0	53.5	E.
D-37	4.2	58.0	57.0	57.0	57.5	60.0	56.5	50.0	53.0	E.
D-38	4.1	58.0	57.0	57.0	57.5	60.0	56.0	50.0	52.3	E.
D-39	4.2	57.0	55.5	56.0	56.2	60.0	56.0	49.0	53.7	E.
D-40	5.2	58.0	56.5	57.0	57.2	60.0	57.5	50.0	54.2	E.
D-48	5.8	61.5	59.5	60.5	60.2	67.0	68.5	60.0	64.2	E.
D-49	2.4	71.5	71.0	71.5	71.5	72.0	72.5	64.0	68.2	E.
D-50	4.2	66.0	65.0	65.5	65.5	70.5	73.0	67.0	68.5	Hands Up
D-51	5.3	66.0	65.0	65.5	65.2	70.5	72.0	65.0	68.0	Hands Up
D-52	2.1	69.5	69.0	69.5	68.2	70.0	71.0	65.0	67.5	Hands Up
D-53	3.4	67.5	67.0	67.5	66.2	72.5	73.0	64.0	66.7	Hands Up
D-54	No Time	69.5	66.0	67.5	66.2	70.0	70.0	65.0	66.0	Hands Up
D-55	4.7	66.0	64.0	67.0	65.5	70.0	71.0	62.0	66.5	Hands Up
D-56	4.2	67.0	64.0	65.5	65.5	70.5	72.0	66.0	68.5	Hands Up
D-57	4.6	69.0	68.5	68.5	69.0	71.5	72.0	66.0	68.5	Hands Up
D-58	2.4	69.5	67.5	67.5	67.5	70.0	72.0	65.0	67.5	Hands Up
D-59	2.1	66.0	66.0	67.0	64.0	67.5	71.5	64.0	65.7	Hands Up
D-60	3.5	68.0	62.0	65.5	62.0	61.0	69.5	62.0	59.0	Hands Up
D-61	4.8	66.0	59.0	60.0	58.2	62.0	62.0	56.0	61.0	Hands Up
D-62	6.2	59.0	52.0	55.5	60.0	64.0	63.0	58.0	59.5	Hands Up
D-63	3.6	60.0	60.0	60.0	58.2	61.5	63.0	56.0	59.5	Hands Up
D-64	3.2	59.5	57.0	58.2	58	62.0	63.0	56.0	59.5	Hands Up
D-65	5.2	59.5	57.0	58						
D-66	6.4									

TABLE 5-D
BIRNEY CAR NO. 55
Analysis of the Time Data from the Trainagraph Record

Run No.	Time BV. to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Main Reservoir, Sec.	Run No.	Time B.V. to to Max. Press. in B.C. Sec.	Time from B.V. to Min. Press. in Emergency Pipe, Sec.
D-1	No Record		D-31	1.01	1.90
D-2	No Record		D-32	.90	1.80
D-3	No Record		D-33	.90	1.80
D-4	No Record		D-34	.79	1.80
D-5	No Record		D-35	.90	1.57
D-6	1.01	1.80	D-36	1.35	1.10
D-7	No Record		D-37	1.24	1.00
D-8	No Record		D-38	1.10	.79
D-9	No Record		D-39	1.10	.90
D-10	No Record		D-40	1.10	.90
D-11	No Record		D-48	1.10	1.00
D-12	1.01	2.30	D-49	1.10	.90
D-13	1.01	1.90	D-50	1.45	1.00
D-14	1.01	2.30	D-51	1.45	1.10
D-15	.90	2.30	D-52	1.00	2.02
D-16	1.35	1.10	D-53	1.10	1.90
D-17	No Record		D-54	1.10	1.70
D-18	1.10	1.10	D-55	1.00	1.80
D-19	1.01	.90	D-56	1.00	1.90
D-20	1.10	.90	D-57	.90	1.90
D-21	1.10	.90	D-58	.90	2.02
D-22	1.23	.90	D-59	1.00	1.35
D-23	1.23	.90	D-60	1.00	1.80
D-24	.90	1.80	D-61	.90	1.80
D-25	.90	1.80	D-62	.90	1.80
D-26	.90	1.90	D-63	.90	1.80
D-27	.90	1.90	D-64	.79	1.90
D-28	.79	1.80	D-65	.90	1.57
D-29	.90	1.70	D-66	1.00	1.90
D-30	.90	1.80			

Average Time for Brake Cylinder Pressure to Reach Maximum:
Hands Up. High Pressure ..... .96 Sec.
Hands Up. Low Pressure ..... .90 Sec.
Emergency High Pressure ..... 1.19 Sec.
Emergency Low Pressure ..... 1.18 Sec.

Average Time for Emergency Pipe Pressure to Reach Minimum:
Hands Op. High Pressure ..... 1.87 Sec.
Hands Up. Low Pressure ..... 1.78 Sec.
Emergency High Pressure ..... .96 Sec.
Emergency Low Pressure ..... .94 Sec.

TABLE 6-D
BIRNEY CAR NO. 55
Analysis of the Speedmeter Record

Run No.	Speed M.P.H.	Stop Time, Seconds	Time from B.V. to Retardation, Seconds	Kind of Braking
D-1	26.2	22.6	- - -	Speed Record
D-2	20.0	135.5	- - -	Coast'g Record
D-3	22.7	153.5	- - -	Coast'g Record
D-4	22.0	161.5	-	Coast'g Record
D-5	6.5	2.3	1.31	Emergency
D-6	6.1	3.0	1.74	Hands Up
D-7	6.2	10.5	1.74	Hands Up
D-8	6.7	5.0	1.74	Hands Up
D-9	6.0	2.3	1.39	Hands Up
D-10	11.0	3.5	1.29	Hands Up
D-11	6.3	2.6	- - - -	Hands Up
D-12	6.0	1.8	- - -	Hands Up
D-13	6.4	2.5	1.50	Hands Up
D-14	9.7	1.6	1.33	Hands Up
D-15	11.5	3.4	1.36	Hands Up
D-16	12.5	3.4	1.12	Emergency
D-17	6.5	2.2	0.96	Emergency
D-18	6.1	2.1	1.07	Emergency
D-19	11.4	3.5	1.15	Emergency
D-20	14.5	4.0	1.00	Emergency
D-21	19.5	5.3	1.04	Emergency
D-22	20.4	5.3	0.88	Emergency
D-23	7.5	2.2	1.00	Emergency
D-24	20.6	5.7	0.80	Hands Up
D-25	7.0	No Stop Indication		Hands Up
D-26	5.2	1.9	1.17	Hands Up
D-27	11.3	3.5	0.83	Hands Up
D-28	12.5	3.6	0.83	Hands Up
D-29	14.7	4.7	0.85	Hands Up
D-30	17.0	4.8	1.15	Hands Up
D-31	6.6	1.9	1.12	Hands Up
D-32	11.5	4.0	1.27	Hands Up
D-33	15.2	5.3	1.17	Hands Up
D-34	19.4	6.4	1.02	Hands Up
D-35	20.0	6.0	1.12	Hands Up
D-36	7.5	3.0	1.31	Emergency
D-37	10.7	4.5	1.45	Emergency
D-38	11.0	4.5	1.33	Emergency
D-39	21.1	6.9	0.96	Emergency
D-40	15.2	5.2	0.64	Emergency
D-41	6.0	3.0	0.00	R.M.
D-42	11.2	13.7	1.12	R.M.
D-43	11.2	8.1	1.60	R.M.
D-44	15.0	- - -	0.80	R.M.
D-45	6.2	5.9	3.33	B.M.
D-46	11.2	8.9	2.88	B.M.
D-47	15.3	12.1	2.33	B.M.
D-48	25.2	8.6	0.97	Emergency
D-49	6.5	2.7	1.17	Emergency
D-50	11.3	4.3	1.24	Emergency
D-51	15.8	- - -	- - -	Emergency
D-52	5.5	1.8	0.88	Hands Up
D-53	11.5	4.1	0.00	Hands Up
D-54	15.2	No Indication	- - -	Hands Up
D-55	14.5	4.7	0.81	Hands Up
D-56	19.5	6.3	0.42	Hands Up
D-57	21.7	6.4	0.00	Hands Up
D-58	7.0	2.3	1.07	Hands Up
D-59	5.7	2.4	1.00	Hands Up
D-60	11.0	3.3	1.00	Hands Up
D-61	15.0	5.1	0.82	Hands Up
D-62	23.0	6.4	0.94	Hands Up
D-63	10.2	3.6	1.33	Hands Up
D-64	5.5	2.0	1.13	Hands Up
D-65	16.0	5.9	0.98	Hands Up
D-66	23.0	6.8	1.04	Hands Up

TABLE 7-D
BIRNEY CAR NO. 55
Analysis of the Time from the Stop Indication to the Beginning of Retardation

Run No.	Kind of Braking	Time from B.V. to Retardation, Seconds
	Hands Up	
D-6	High Press. Air	1.74
D-9	High Press. Air	1.39
D-10	High Press. Air	1.29
D-12	High Press. Air	0.00
D-13	High Press. Air	1.50
D-14	High Press. Air	1.33
D-15	High Press. Air	1.36
D-24	High Press. Air	0.80
D-26	High Press. Air	1.17
D-27	High Press. Air	0.83
D-28	High Press. Air	0.83
D-29	High Press. Air	0.85
D-30	High Press. Air	1.15
D-52	High Press. Air	0.88
D-53	High Press. Air	0.00
D-54	High Press. Air	----
D-55	High Press. Air	0.81
D-56	High Press. Air	0.42
D-57	High Press. Air	0.00
	Average	0.84
	Hands Up	
D-31	Low Press. Air	1.12
D-32	Low Press. Air	1.27
D-33	Low Press. Air	1.17
D-34	Low Press. Air	1.02
D-35	Low Press. Air	1.12
	Average	1.14
	E.	
D-5	High Press. Air	1.31
D-16	High Press. Air	1.12
D-17	High Press. Air	0.96
D-18	High Press. Air	1.07
D-19	High Press. Air	1.15
D-20	High Press. Air	1.00
D-21	High Press. Air	1.04
D-22	High Press. Air	0.88
D-23	High Press. Air	1.00
D-48	High Press. Air	0.97
D-49	High Press. Air	1.17
D-50	High Press. Air	1.24
D-51	High Press. Air	----
	Average	1.08
	E.	
D-36	Low Press. Air	1.31
D-37	Low Press. Air	1.45
D-38	Low Press. Air	1.33
D-39	Low Press. Air	0.96
D-40	Low Press. Air	0.64
	Average	1.14
D-41	R.M.	0.00
D-42	R.M.	1.12
D-43	R.M.	1.60
D-44	R.M.	0.80
	Average	0.88
D-45	B.M.	3.33
D-46	B.M.	2.88
D-47	B.M.	2.33
	Average	2.85
	LIGHT LOADED TESTS	
	Hands Up	
D-59	High Press. Air	1.07
D-60	High Press. Air	1.00
D-61	High Press. Air	1.00
D-62	High Press. Air	0.83
	Average	.97
	Hands Up	
D-63	Low Press. Air	1.33
D-64	Low Press. Air	1.13
D-65	Low Press. Air	0.98
D-66	Low Press. Air	1.04
	Average	1.12

TABLE 8-D
BIRNEY CAR NO. 55
Braking Rates at Different Speeds

Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.	Run No.	Speed M.P.H.	Braking Rate M.P.H.P.S.
D-19	15.6	0.00	D-34	24.6	2.58
	15.3	1.91		22.0	3.62
	14.7	1.75		17.6	4.22
	14.2	1.71		13.1	3.68
	9.9	6.15		8.7	5.03
D-20	17.8	2.30		3.1	4.36
	14.4	3.26	D-35	23.9	2.97
	14.1	4.78		19.4	4.52
	10.6	5.23		13.4	4.28
	7.3	3.82		8.2	4.67
D-21	22.2	1.54		2.9	4.70
	21.4	2.67	D-38	13.3	4.04
	20.0	3.45		10.0	4.76
	18.1	4.81		6.9	4.09
	15.5	5.14		2.8	4.34
	12.5	4.39	D-40	18.7	1.08
	8.1	5.64		16.4	3.85
	2.6	5.33		12.4	3.25
D-22	23.5	1.87		9.0	4.62
	22.8	1.89		3.4	4.27
	21.4	5.34	D-48	26.7	4.49
	19.3	4.37		23.6	3.47
	16.0	5.70		15.3	3.28
	13.4	3.38		9.7	4.05
	10.2	4.95		3.5	4.82
	2.8	4.47	D-49	9.1	1.31
D-23	10.5	.55		7.4	4.45
	9.4	5.35		3.0	3.94
	5.7	5.89	D-51	18.7	2.69
	1.7	4.58		15.6	2.29
D-24	24.5	3.29		11.6	4.00
	21.7	4.60		4.4	4.88
	18.9	3.81	D-53	15.7	.88
	16.0	5.83		13.7	4.47
	13.0	4.38		8.6	5.72
	10.6	4.73		2.9	4.06
	8.3	4.60	D-55	19.0	0.00
	3.5	4.71		17.2	4.75
D-25	9.6	0.00		13.0	3.89
	8.9	3.24		8.1	4.56
	7.4	4.77		2.9	4.41
	3.4	4.70	D-57	26.7	0.00
D-26	7.4	.44		25.9	1.94
	3.6	5.20		22.0	4.91
D-27	15.6	0.00		15.4	5.11
	14.1	4.65		8.9	4.70
	11.4	4.46		3.0	4.84
	8.2	7.28	D-61	19.0	4.81
	3.2	5.19		14.0	5.34
D-28	16.2	0.00		8.9	5.11
	14.9	4.59		3.3	4.73
	11.8	4.55	D-62	27.8	3.21
	7.9	5.53		25.3	3.70
	2.8	5.75		21.9	2.96
D-29	15.3	1.06		16.8	5.03
	13.0	6.00		10.0	4.50
	10.1	4.20		3.4	5.03
	7.6	5.75	D-63	13.1	3.89
	3.0	4.65		9.5	4.96
D-30	20.5	.89		3.6	4.93
	19.3	2.68	D-64	6.7	3.13
	16.4	5.32		2.5	5.14
	13.0	6.01	D-65	19.8	4.28
	9.3	4.88		16.4	3.65
	3.5	5.35		11.3	5.34
D-32	14.1	4.48		4.0	4.48
	11.1	4.95	D-66	27.9	2.29
	8.0	6.11		24.0	6.00
	3.2	5.00		18.7	4.74
D-33	20.3	0.00		11.7	5.12
	17.9	4.65		4.0	5.10
	13.1	4.95			
	8.1	4.90			
	2.7	4.75			

TABLE 9-D
BIRNEY CAR NO. 55
Comparison of Stopping Distances as Determined by Several Methods.

Run No.	Measured Distance, Feet	Distance by Chronograph		Distance by Revolution Counter		Kind of Braking
		Revolution of Car Wheel	Distance Feet	Revolution of Car Wheel	Distance Feet	
D-5	30.0			5.0	32.3	E. Maximum Pressure
D-6	25.6			4.0	25.4	Hands Up
D-7						Maximum Pressure
D-8						Maximum Pressure
D-9	21.0			3.5	22.6	Maximum Pressure
D-10	53.7			8.0	51.6	Maximum Pressure
D-11						Maximum Pressure
D-12	20.6			3.0	19.4	Maximum Pressure
D-13	23.0	3.0	19.3	3.5	22.6	Maximum Pressure
D-14	37.0			5.0	32.3	Maximum Pressure
D-15	56.0			8.0	51.6	Maximum Pressure
D-16	63.7			9.0	58.0	E. Maximum Pressure
D-17	33.0	2.0	12.9	3.5	22.6	E. Maximum Pressure
D-18	25.0	2.0	12.0	4.0	25.8	E. Maximum Pressure
D-19	54.6	7.0	45.1	8.0	51.6	E. Maximum Pressure
D-20	76.5	9.0	58.0	12.0	77.5	E. Maximum Pressure
D-21	125.4	16.5	106.3	19.0	122.5	E. Maximum Pressure
D-22	134.1	17.0	109.6	20.0	129.0	E. Maximum Pressure
D-23	29.5	3.5	22.6	4.0	25.6	E. Maximum Pressure
D-24	134.9	18.0	116.0	21.0	135.5	Hands Up Max. Press.
D-25	27.8	3.0	19.3	6.0	38.7	Hands Up Max. Press.
D-26	17.5	1.5	9.7	2.0	12.9	Hands Up Max. Press.
D-27	56.2	7.0	46.4	8.0	51.6	Hands Up Max. Press.
D-28	63.5	8.0	51.6	9.0	58.0	Hands Up Max. Press.
D-29	81.1	11.0	70.9	12.0	77.5	Hands Up Max. Press.
D-30	98.2	13.0	83.8	14.0	90.3	Hands Up Max. Press.
D-31	20.9	2.0	12.9	2.0	12.9	Hands Up Max. Press.
D-32	59.0	7.5	48.4	8.0	51.6	Hands Up Max. Press.
D-33	94.2	12.5	81.0	13.0	83.7	Hands Up Max. Press.
D-34	137.3	19.0	122.4	21.0	135.5	Hands Up Max. Press.
D-35	149.5	20.0	129.0	22.0	142.0	Hands Up Max. Press.
D-36	41.0	3.5	23.9	6.0	38.7	E. Minimum Pressure
D-37	65.0			9.0	58.1	E. Minimum Pressure
D-38	68.5	8.5	55.0	10.0	64.5	E. Minimum Pressure
D-39	175.3	23.0	148.0	25.0	161.5	E. Minimum Pressure
D-40	98.6	13.0	83.8	14.5	93.4	E. Minimum Pressure
D-48	261.8	33.0	212.7	40.0	258.0	E. Maximum Pressure
D-49	28.5	3.0	19.3	4.0	25.8	E. Maximum Pressure
D-50	61.0			8.0	51.6	E. Maximum Pressure
D-51	105.6	14.0	90.1	15.0	96.6	E. Maximum Pressure
D-52	21.0	3.0	19.3	3.5	22.6	Hands Up Max. Press.
D-53	57.6	7.5	48.3	9.0	58.1	Hands Up Max. Press.
D-54	92.8			14.0	90.3	Hands Up Max. Press.
D-55	84.0	11.5	74.1	13.0	83.7	Hands Up Max. Press.
D-56	137.8	18.5	119.0	20.0	129.0	Hands Up Max. Press.
D-57	157.3	22.0	142.0	23.0	148.5	Hands Up Max. Press.
D-58	28.0	3.0	19.3	4.0	25.8	Hands Up Max. Presss
D-59	21.0	2.5	16.1	3.0	19.4	Hands Up Max. Press.
D-60	51.8	7.0	45.0	7.0	45.2	Hands Up Max. Press.
D-61	89.4	12.0	77.3	13.5	86.9	Hands Up Max. Press.
D-62	169.6	23.5	152.0	25.0	161.5	Hands Up Max. Press.
D-63	50.6	6.5	42.0	6.0	38.7	Hands Up Min. Press.
D-64	21.5	2.0	12.9	3.0	19.5	Hands Up Min. Press.
D-65	100.1	13.0	83.8	14.0	90.2	Hands Up. Min Press.
D-66	167.6	24.0	155.0	25.0	161.5	Hands Up Min. Press.

TABLE 10-D
BIRNEY CAR NO. 55
Comparison of Stopping Time in Seconds as Determined by Several Methods

Run No.	Chrono-graph	Stop Watch	Traina-graph	Speed meter	Kind of Braking
D-5	---	3.1	--	2.3	E. High Pressure
D-6	---	2.8	3.1	3.0	Hands Up High Press.
D-9	2.5	2.5	---	2.4	Hands Up High Press.
D-10	3.7	3.4	--	3.5	Hands Up High Press.
D-12	3.8	2.2	2.2	1.8	Hands Up High Press.
D-13	2.4	2.2	2.5	2.5	Hands Up High Press.
D-14	2.9	2.9	3.0	1.6	Hands Up High Press.
D-15	3.3	3.6	3.6	3.4	Hands Up High Press.
D-16	---	3.8	3.7	3.4	E. High Pressure
D-17	2.3	2.5	---	2.2	E. High Pressure
D-18	2.2	2.7	2.1	2.1	E. High Pressure
D-19	3.8	3.6	3.7	3.5	E. High Pressure
D-20	4.0	4.5	3.8	4.0	E. High Pressure
D-21	5.4	5.8	5.5	5.3	E. High Pressure
D-22	5.6	6.0	5.6	5.3	E. High Pressure
D-23	2.5	2.5	2.7	2.2	E. High Pressure
D-24	5.9	6.0	6.2	5.7	Hands Up High Press.
D-25	2.6	2.4	1.9	---	Hands Up High Press.
D-26	2.0	1.8	2.2	1.9	Hands Up High Press.
D-27	3.5	3.6	3.5	3.5	Hands Up High Press.
D-28	3.7	4.0	3.7	3.6	Hands Up High Press.
D-29	4.6	4.4	4.5	4.7	Hands Up High Press.
D-30	4.9	5.1	5.0	4.8	Hands Up High Press.
D-31	2.3	2.4	2.4	1.9	Hands Up Low Press.
D-32	3.7	4.0	3.9	4.0	Hands Up Low Press.
D-33	4.9	4.9	4.8	5.3	Hands Up Low Press.
D-34	6.3	6.5	6.7	6.4	Hands Up Low Press.
D-35	6.4	6.5	6.7	6.0	Hands Up Low Press.
D-36	2.7	3.3	3.0	3.0	E. Low Pressure
D-37	---	4.2	4.2	4.5	E. Low Pressure
D-38	4.2	4.3	4.1	4.5	E. Low Pressure
D-39	7.2	7.6	7.2	6.9	E. Low Pressure
D-40	5.3	5.3	5.2	5.2	E. Low Pressure
D-41	3.0	3.4	--	3.0	R.M.
D-42	13.7	6.0	-	13.7	R.M.
D-43	8.1	7.7	---	8.1	R.M.
D-44	10.5	10.3	---	-	R.M.
D-45	6.1	6.4	--	5.9	B.M.
D-46	8.7	9.1	---	8.9	B.M.
D-47	12.2	13.8	---	12.1	B.M.
D-48	8.6	9.4	8.8	8.6	E. High Pressure
D-49	2.6	2.9	2.8	2.7	E. High Pressure
D-50	---	4.0	4.2	4.3	E. High Pressure
D-51	5.3	5.5	5.3	--	E. High Pressure
D-52	2.3	2.1	2.1	1.8	Hands Up High Press.
D-53	3.9	3.6	3.4	4.1	Hands Up High Press.
D-54	---	5.0	---	---	Hands Up High Press.
D-55	4.8	4.7	4.7	4.7	Hands Up High Press.
D-56	5.9	6.2	6.2	6.3	Hands Up High Press.
D-57	6.4	6.3	6.6	6.4	Hands Up High Press.
D-58	2.4	2.4	2.4	2.3	Hands Up High Press.
D-59	2.2	2.2	2.1	2.4	Hands Up High Press.
D-60	3.4	3.3	3.5	3.3	Hands Up High Press.
D-61	4.7	4.8	4.8	5.1	Hands Up High Press.
D-62	6.6	6.4	6.2	6.4	Hands Up High Press.
D-63	3.5	3.4	3.6	3.6	Hands Up Low Press.
D-64	2.1	2.4	2.2	2.0	Hands Up Low Press.
D-65	5.2	4.8	5.2	5.9	Hands Up Low Press.
D-66	6.6	6.6	6.6	6.8	Hands Up Low Press.

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